INTERVENTIONS ON ANCIENT BUILDINGS STRUCTURE

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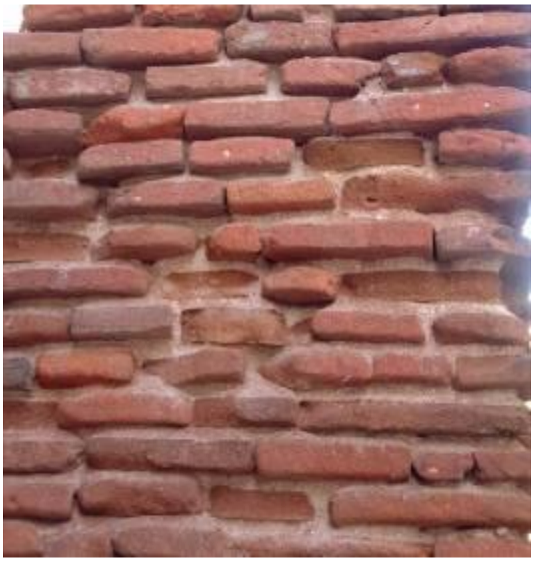
INTRODUCTION

Along our experience of more than twenty years in consolidation, restoration and rehabilitation of ancient buildings, our materials and techniques of intervention are getting "softer", on the contrary of the usual meaning of structure as the stiffest part of a building.

We use the term "soft" in a wide sense when we talk about RESTORING WITH SOFT MATERIALS: we think of using not so stiff materials as the ones we are trying to preserve and reinforce (hydraulic lime, plastic mortar, deformable wood, ductile anchors and sewings, etc), as well as to "lightness" in an intervention, where new materials (very localized actions, minimum structures, glass and timber as complementary materials, etc) don't stand out over preserved ones, and hardly modify the way the original structures work.



The pictures above show the effect of filling with stiffer more waterproof cement mortar on a traditional brick masonry affected by water flow from the retained back soil: the brick becomes the "sacrificed" material, instead of the mortar.

In the course of time, brick turns into sand and disappears, whereas a "soft" restoration would have refilled again with lime mortar. It is more desirable a slow damage on this material than the disappearance of the main one.

We will summarize some examples of already finished restorations, where our intervention is as reduced as possible, in order to guarantee the preservation of the building: hydraulic lime injections to reinforce the foundations of a tower, lime concrete to preserve walls, techniques of under-ventilation to dry dampness, geologic restoration of urban cliffs, etc.

The report will be arranged depending on the main material in intervention: from the most simple to the most innovative ones.

1. MUD, PLASTER

Bab al Mardum Mosque (Cristo de la Luz), Toledo

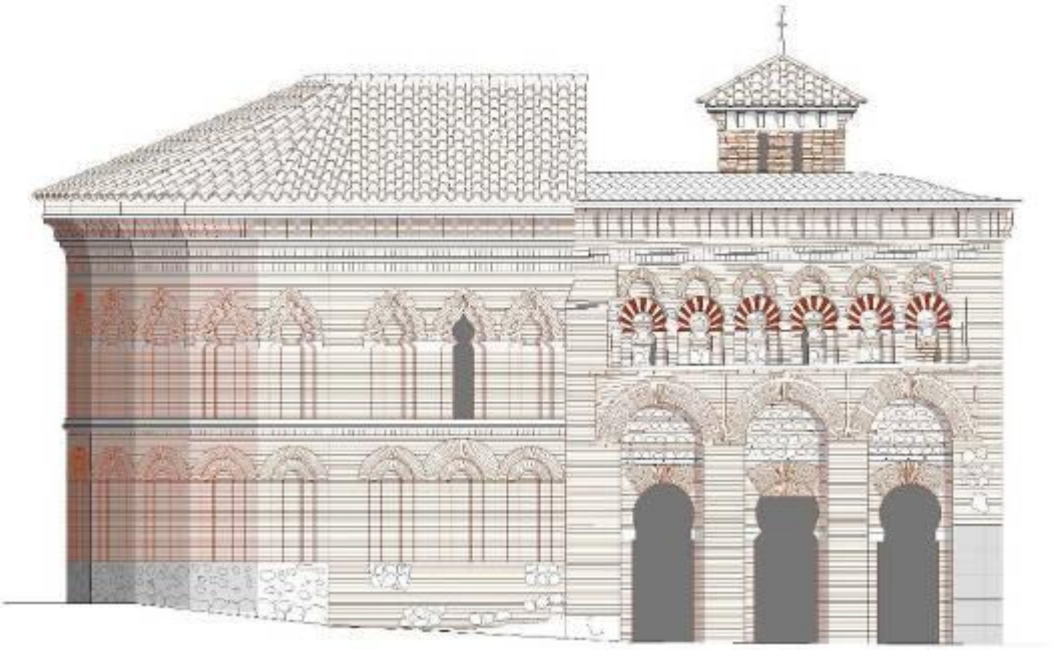
It is an example of a more than ten centuries old ductile structure.

Besides the surprising use of plaster mortar mixed with wood shavings to gain elasticity for its masonry; after an intervention with archaeological methods, we discovered the original roof system: a filling of clay with lime among and over the vaults forms the external shape of a single dome with a central lantern.

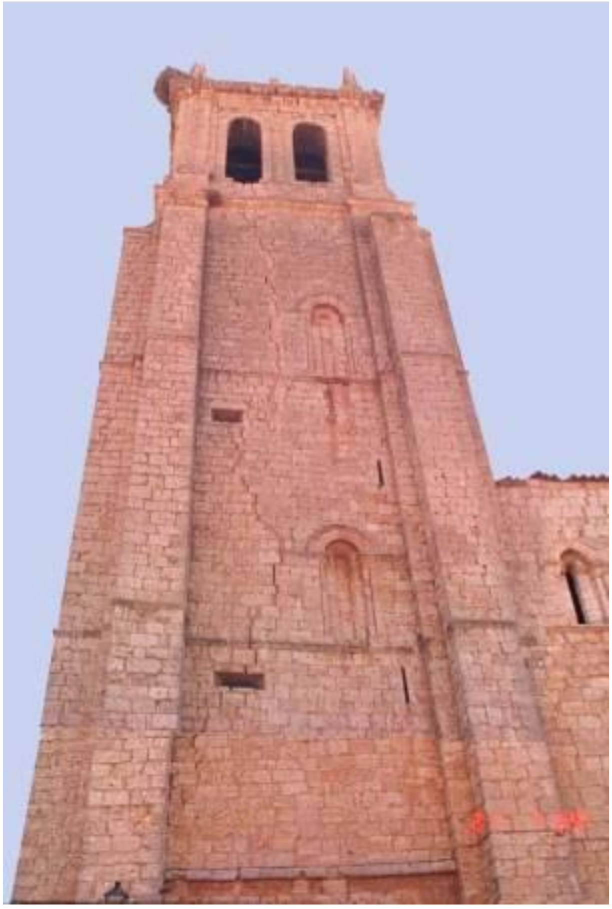
We can see below the main cross-section of the building before the restoration, with a wood roof structure that obstructed the lantern; and the recovery of the original system after the restoration.

Repair of broken vaults with plaster, and filling of clay and lime to recover the original outline of the roof.

Above, just finished roof with restored central lantern. Below, the drawing shows the Christian extension: the mudejar apse attached to the mosque two centuries after its building.



2. FAT LIME, HYDRAULIC LIME



Church in Villamuriel del Cerrato (Palencia)

The tower showed serious cracks, and was fast becoming ruins. The process was monitorized, and we could see an internal disintegration of masonry.

After refilling external ashlars, we injected hydraulic lime to fulfill and join together the masonry core, up to 5% of walls total volume.

At the same time as lime reached disintegrated areas, monitorized deformations got less and less significant up to complete stability, as graphics below shows.

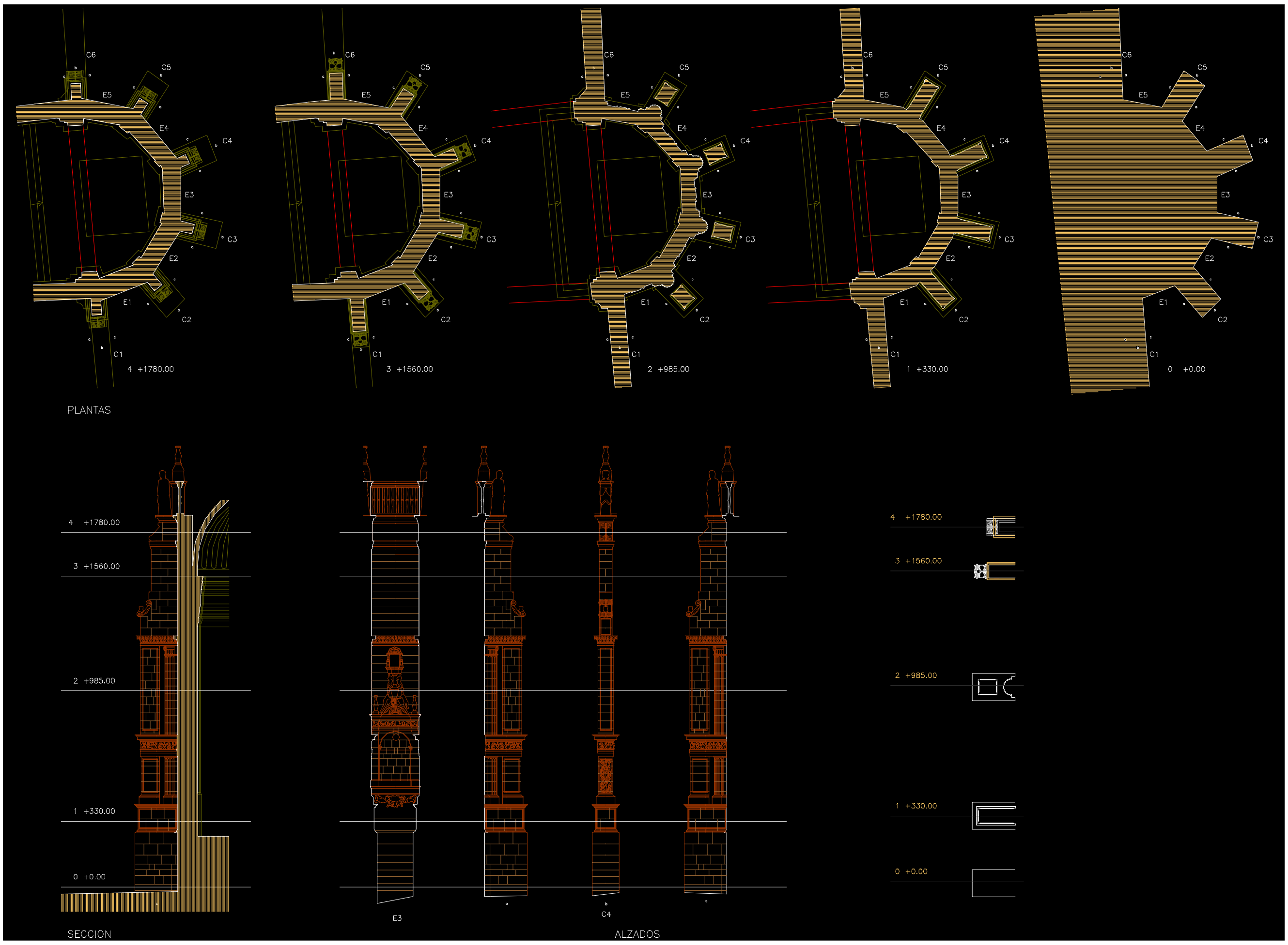
The picture on the right shows the appearance of the tower after its restoration.

3. LIME MORTAR

Sta. María del Salvador Church in Chinchilla (Albacete)

At this magnificent church, gothic, renaissance and baroque styles are merged.

The most important element of this church is the apse, where an unfinished renaissance extension for the former gothic church just begun.

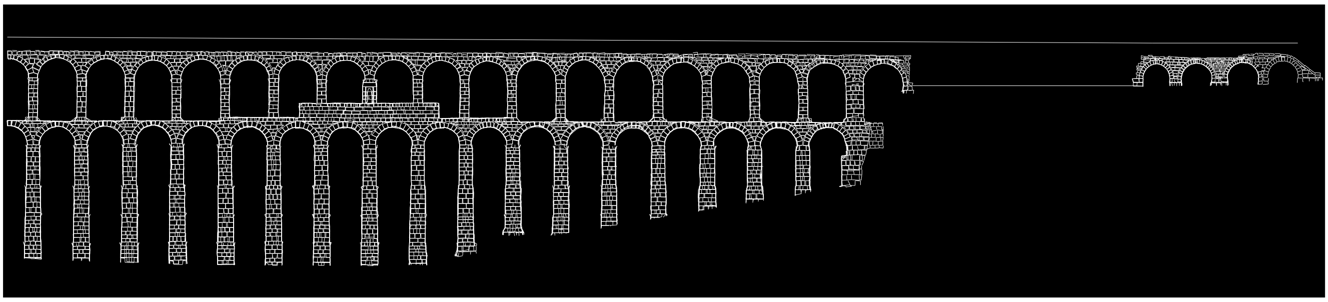


Apse plans, evidently influenced by Diego de Siloé architecture.

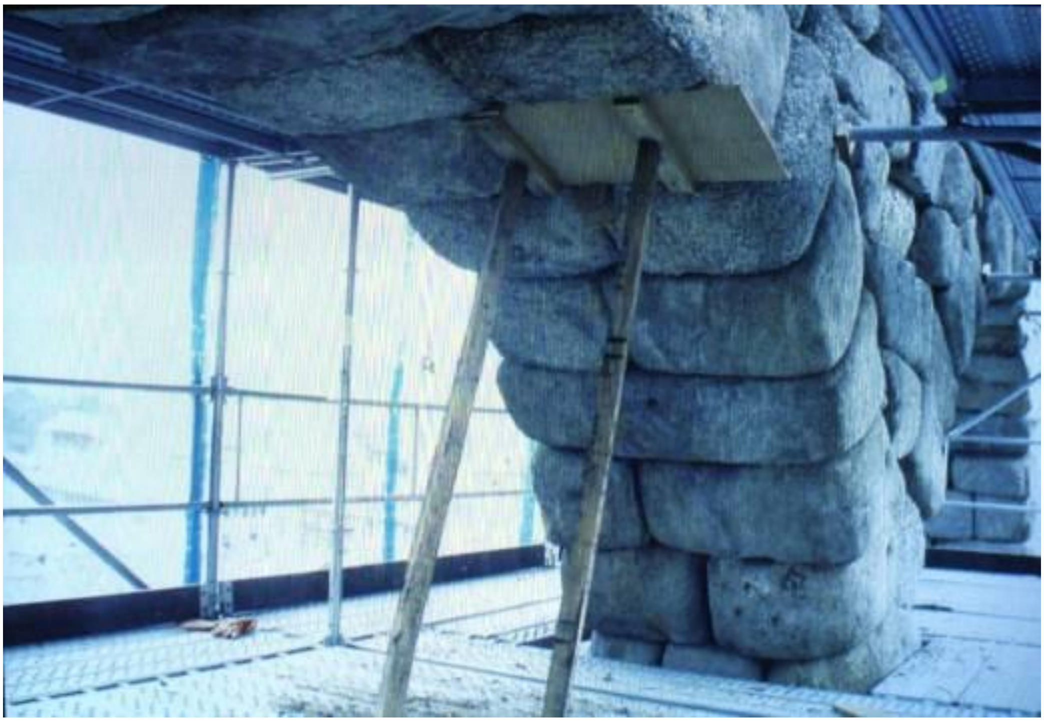
Such a “classic” material in ancient buildings as lime mortar, is perfect to make “tooth-like” fillings in damaged and eroded ashlars, at a slightly lower level than the surface.
This solution is always more desirable, as it preserves the whole original wall, and keeps a visible difference between old and new; than cladding with new stone, cutting out the original masonry, so that it looks unnaturally renovated.

We can even use lime mortar, with an internal glass fiber frame, to rebuild disappeared volumes and decorative elements.

4. WHITE CEMENT MORTAR



Roman aqueduct, Segovia



Instead of substituting ashlars, which involves dismantling arches and pillars structures, we made localized completions with artificial stone (cement mortar is even less resistant than the old aqueduct granite), keeping every ashlars independence, and not joining it with adjacent ones.
This solution is “passive”, it does not imply any change in load routes (the picture above shows a shuttering, not a prop), nor the contrary, as new material begins to work only little by little, when the structure needs it.

5. LIME MORTAR

Atienza Walls (Guadalajara)

These huge sections are built with two external stone masonry sheets of little ashlars, and internal cyclopean (with great rocks) concrete filling.
Lime concrete is similar to the original material, and useful to restore cracks and disappeared sectors.
We were specially careful with external texture, in order to make it as variable as the original with changing sunlight angle.
We used narrow plank shuttering, cut out against the original wall's remains, leaving current sections at a slightly lower level than remaining ones.

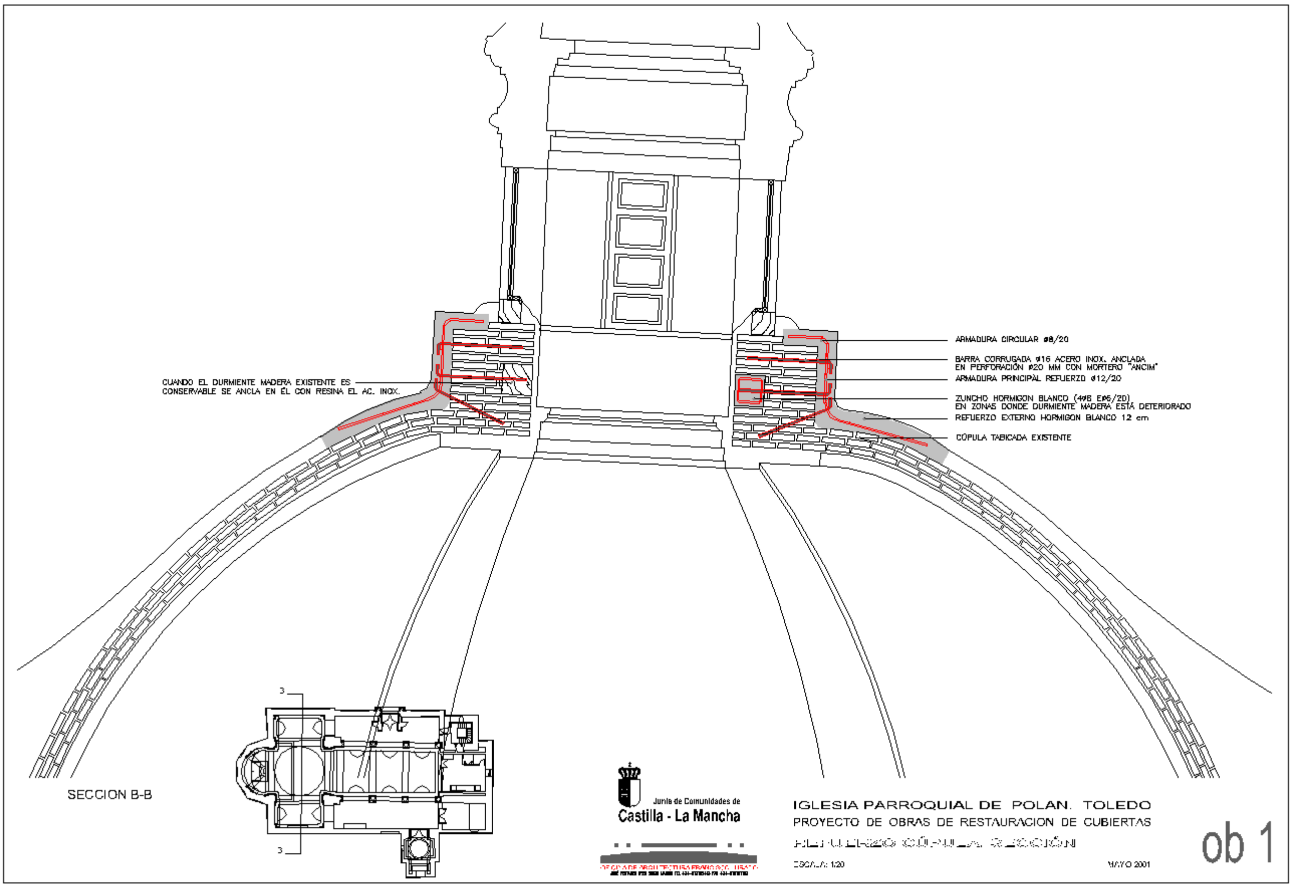
The same material is used for eroded rock foundations. We kept the most projecting stones… and we built a completely artificial new "rock", with triangular planes, as an expressive origami.

Tenerías Arab Baths in Toledo

In this case, lime concrete is used to rebuild disappeared vaults. Our method is the most conservative, as we preserve even the slightest original masonry remain to integrate it in reconstruction.

6. REINFORCED CONCRETE

Dome at Parish Church in Polán (Toledo)



Reinforced concrete is usually rejected among “purists” as unconnected with traditional materials, but sometimes, like in this case, it is the most suitable material to strengthen the dome’s bent lantern without changing the outline: local reinforcements are placed only where they are strictly necessary.

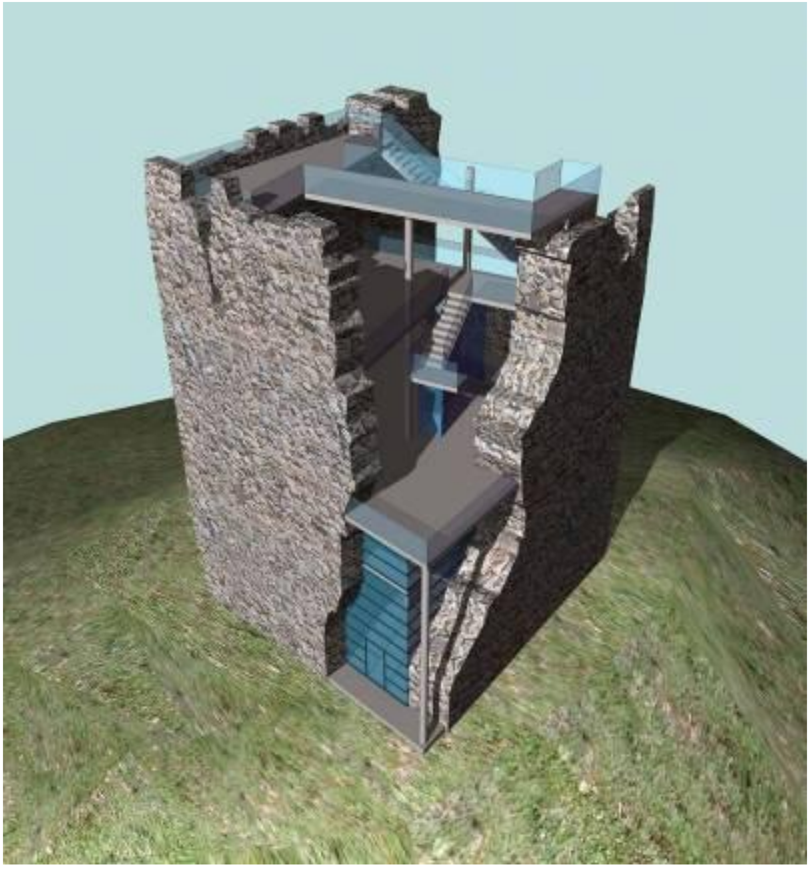
Cupola drum during restoration, when damaged masonry was uncovered.

Already consolidated dome, with a new lead cover.

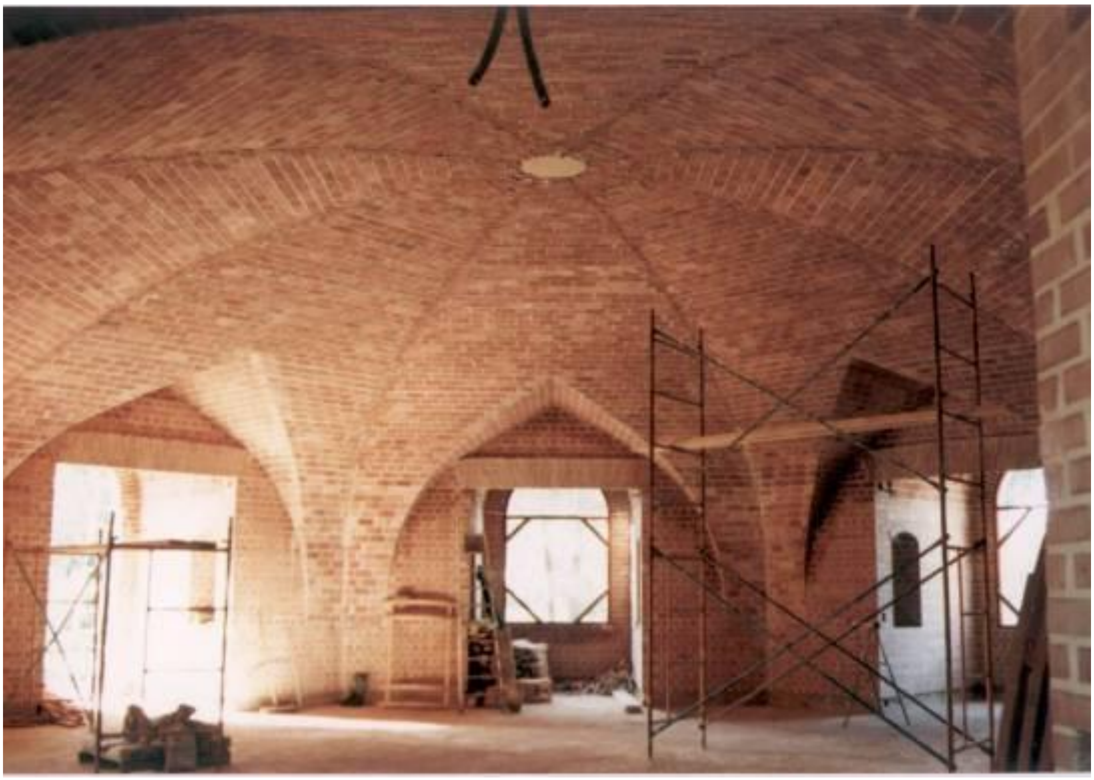
Castrovido Castle, in Salas de los Infantes (Burgos)

In this case, white reinforced concrete lets us build a minim structure that anchors on, leans on, and braces the powerful remains of medieval masonry, or a rebuilding of them made by anastilosis of fallen material.
At the same time, this new structure recovers former levels inside the tower, making them accessible up to the battlement.

Computer model of restored tower, now used as a museum.



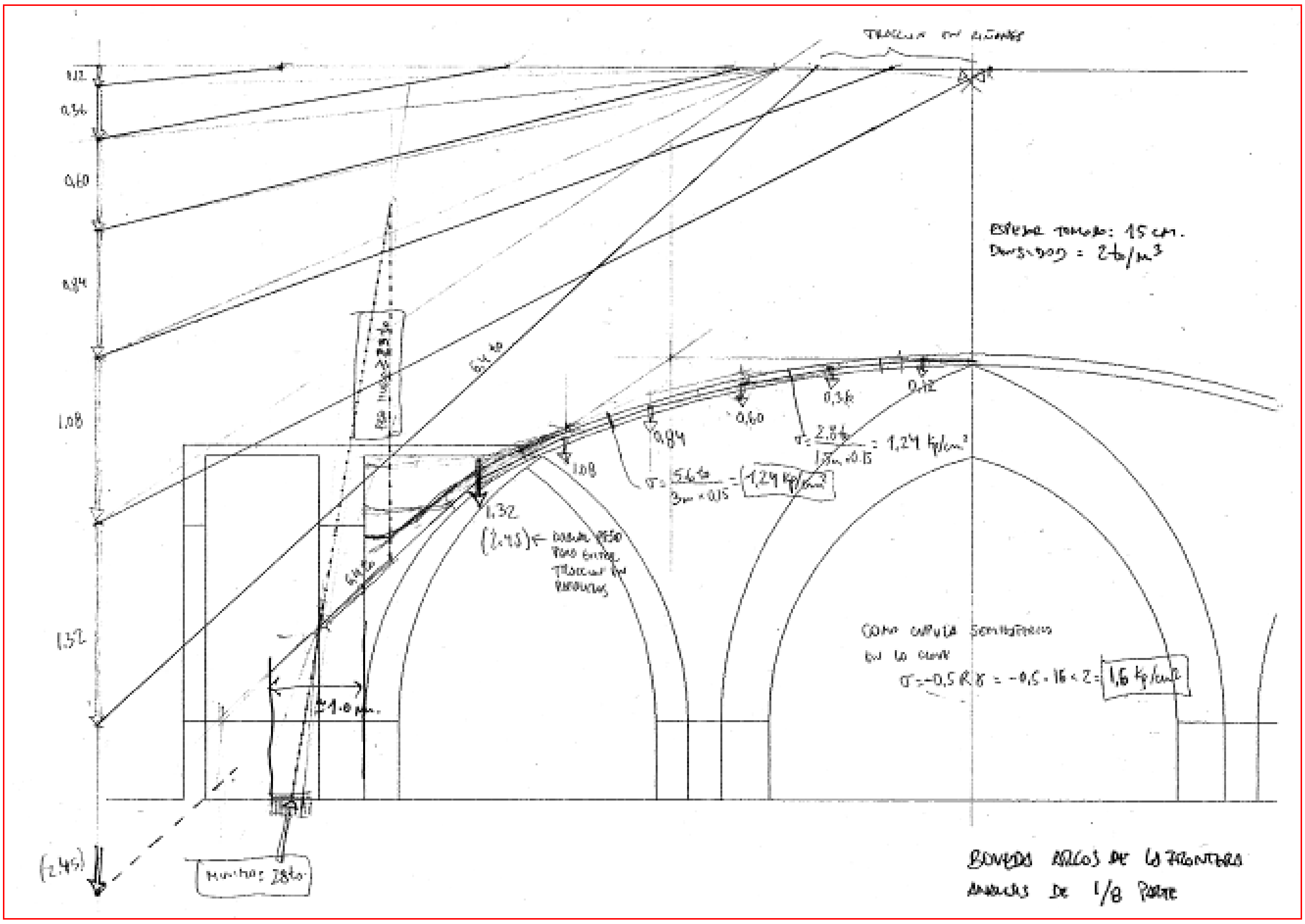
7. BRICK



Vault in Arcos de la Frontera, Cádiz (reproduction of Carlos V Palace crypt in Alhambra, Granada)

Although the original material is stone, this brick can reproduce the traditional building system of "tabicadas" vaults (built with bricks on flat way). This one has a 14 meters span.

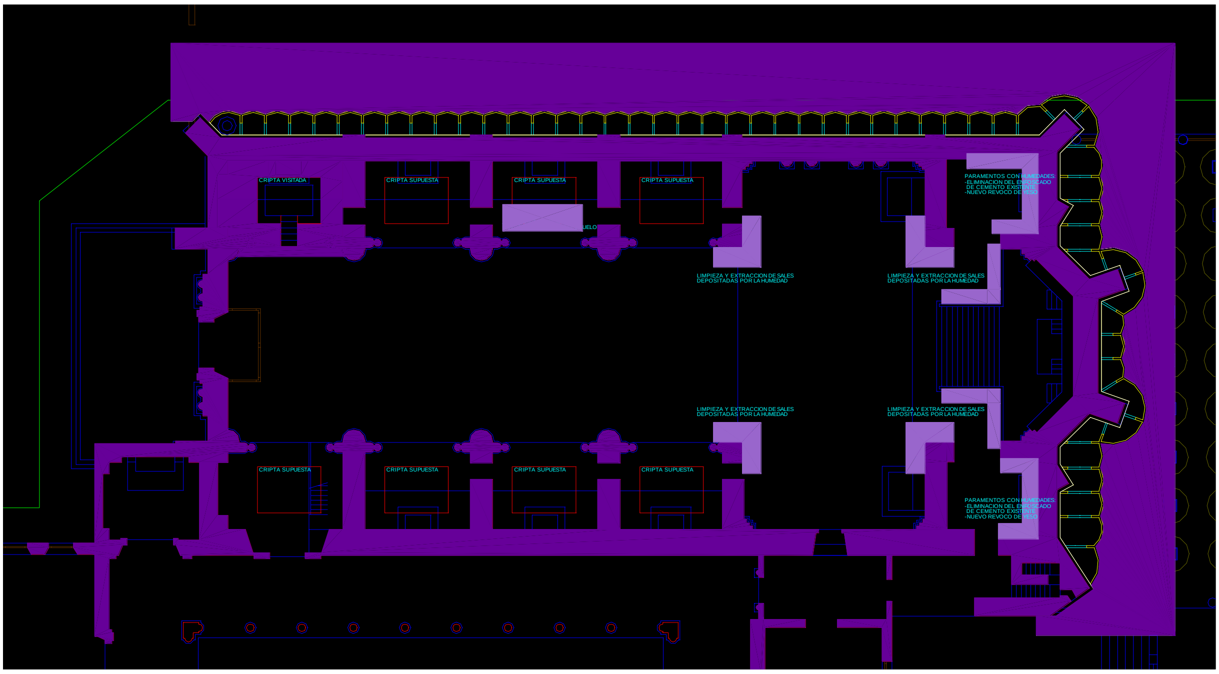
Timber elements are not exactly centering, but three-dimensional guidelines of the vault geometry.
The lunette stiffness, as well as the thickness of contour walls, made up with permanent brick shuttering and internal filling of local soil, allow workers to build the first layer of brick, stuck with plaster, without props, 7 meters above the ground. Two additional crossing brick layers, this time with lime mortar, will complete the definitive thickness.



Even the vault size was determined with a graphic method: the base thickness is calculated to avoid any tensile stress.
Once the vault was closed with the keystone (an octagonal piece), the workers, who had never built anything like this, trusted the stiffness of the building, even though it had not any steel at all.

San Jerónimo de Granada Monastery. Perimetral underground "cámara bufa" (ventilation cavity).

Brick is now used to build vertical vaults to retain soil, as well as flying-buttress-like half-arches against the building foundations, to create a cavity to ventilate the damp masonry.



Brick is easy to handle, and allows water to flow through it, so that vertical vaults are free of water pressure on its back surface.

Brick can also be used to make the lower slab and the gutter to channel the water inside the cavity. It is directly leaning on the soil, without any mortar, in order to improve evaporation through it.

One can walk along the cavity and surround the church foundations.
There are perforations open to indoor crypts, and ventilation grilles open to the street above, so that a permanent draught dries the natural dampness of soil, that before the rehabilitation used to come to the surface and condense inside the church through the marble paving.

San Sebastián de Requena Church, Valencia.

In this case, brick is used like cobblestone, making strips of brick without mortar, and filling the gaps with sand to fix it. The result is a perspiring pavement, adaptable to the lower irregular rock surface.

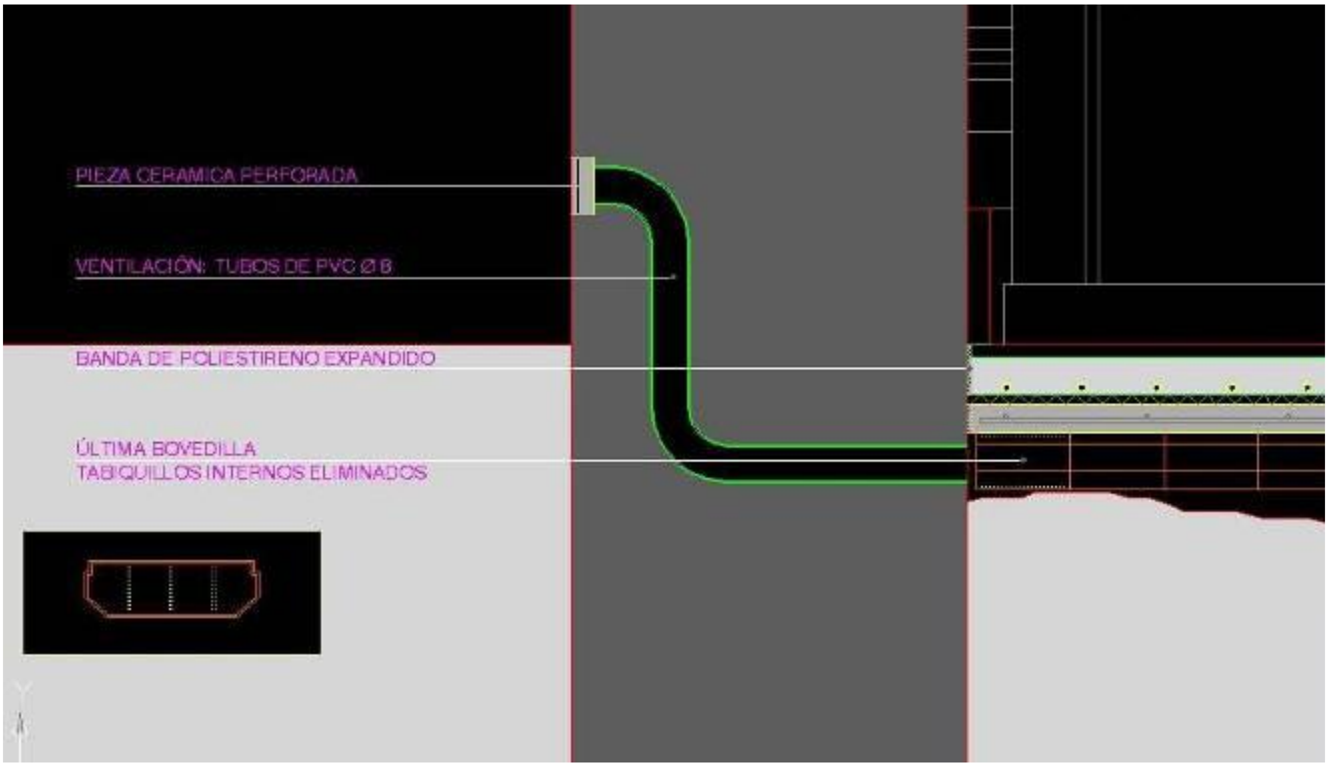
8. CERAMIC FLOORING BLOCKS

Indoor paving. Parish Church in Polán (Toledo)

The pavement we found (it was not the original one), made up with hydraulic floor tiles, was loose and damaged because of dampness, as it was leaning directly on the soil.

We designed for the indoor rehabilitation a new granite paving, leaning on a concrete slab with pipes for underfloor heating.

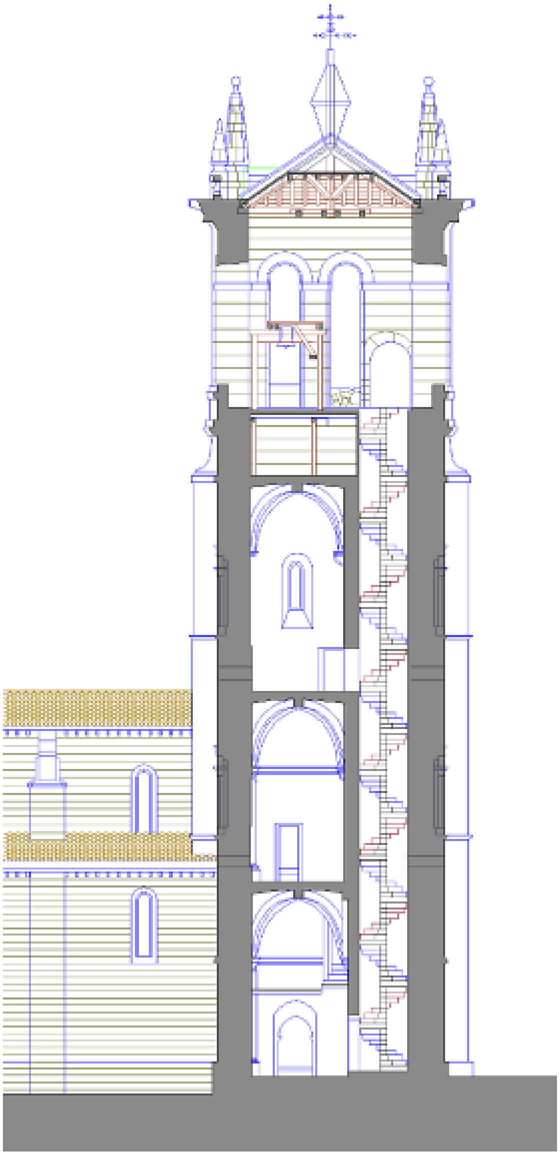
In order to allow subsoil dampness evaporation, we made a ventilated slab, with ceramic flooring blocks under the concrete.
The blocks are face down, aligned, directly leaning on the soil (in this case soil with superficial graves and tombs), and open to two opposite facades, with different sun heating, to get passive ventilation. On the blocks, we place a plastic sheet, and next, the steel rods to reinforce the slab, the heating, and the pavement.
To give an idea of the clay pieces strength, they bore a heavy crane that came inside to paint the dome, once the paving was finished.



9. STONE MASONRY

Mahón harbor cliffs, Menorca.
Stone masonry is “softer” than projecting damaged rocks, and is used to reinforce hollows and fragile faces of rock.

10.TIMBER

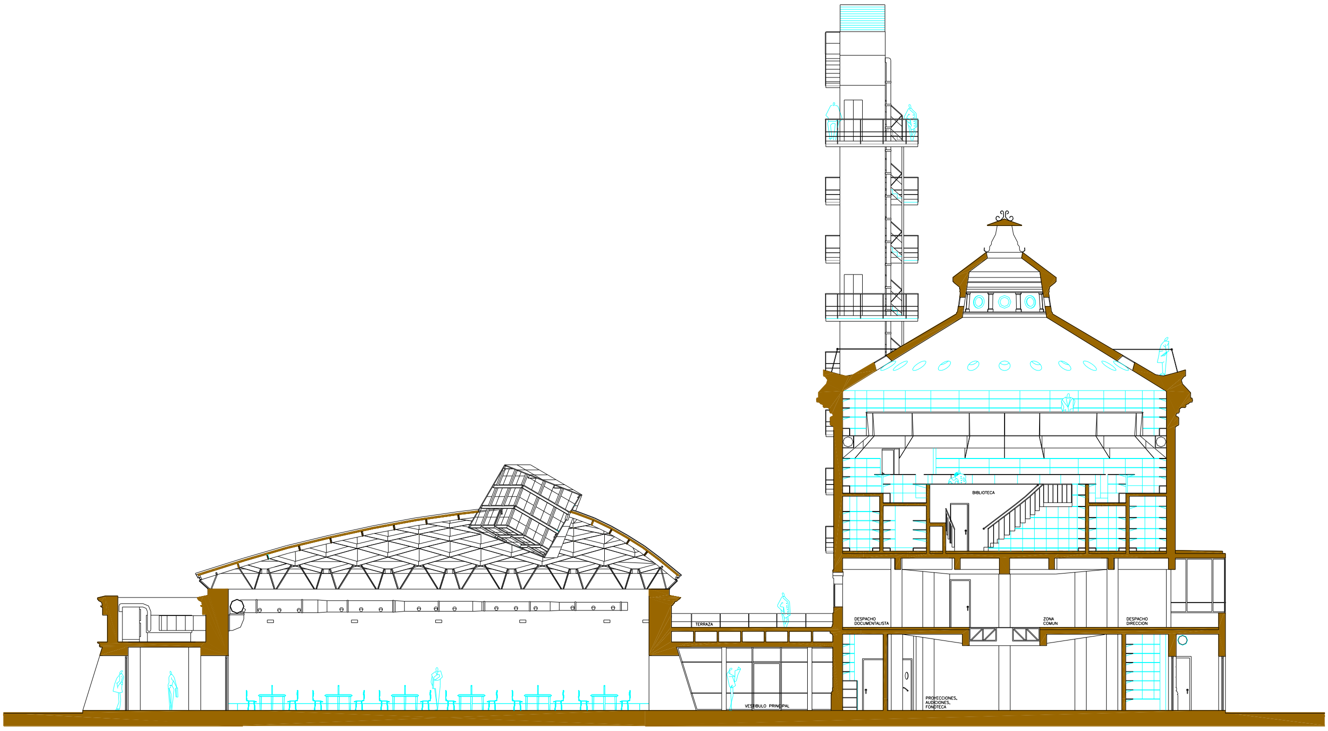


Bell tower framework. Church inVillamuriel del Cerrato, Palencia.

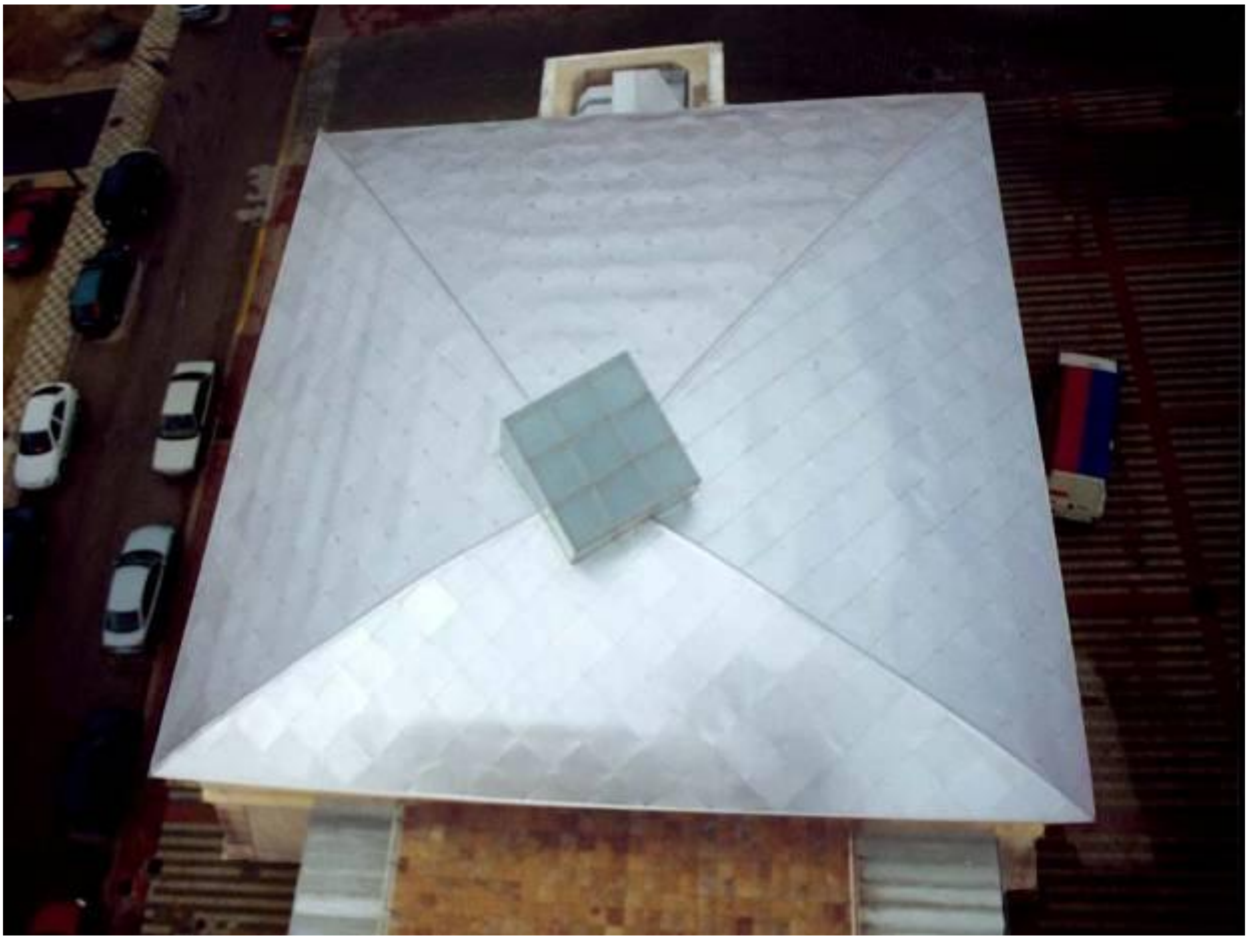
The structure is set up with timber ribs, reflecting the projection of the gothic vaults below, and fenolic plywood. Over this surface, only a brick without mortar paving.

Central Library. Depósitos del Sol, Albacete.

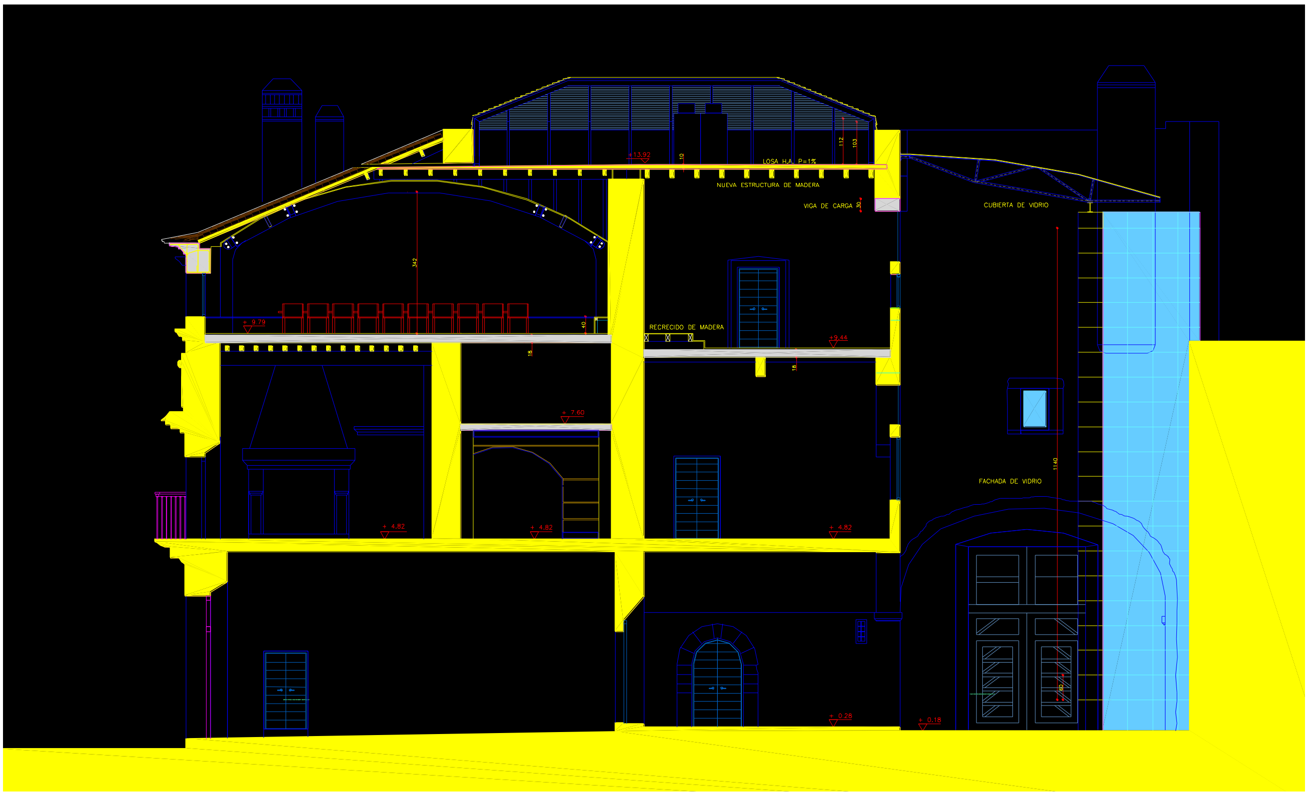
Former water tanks were restored to become the Town Library and complementary areas.
For the large square tank, 20x20 m, now the reading room, we set up a structure of timber beams and fenolic plywood, with an external aluminium layer.

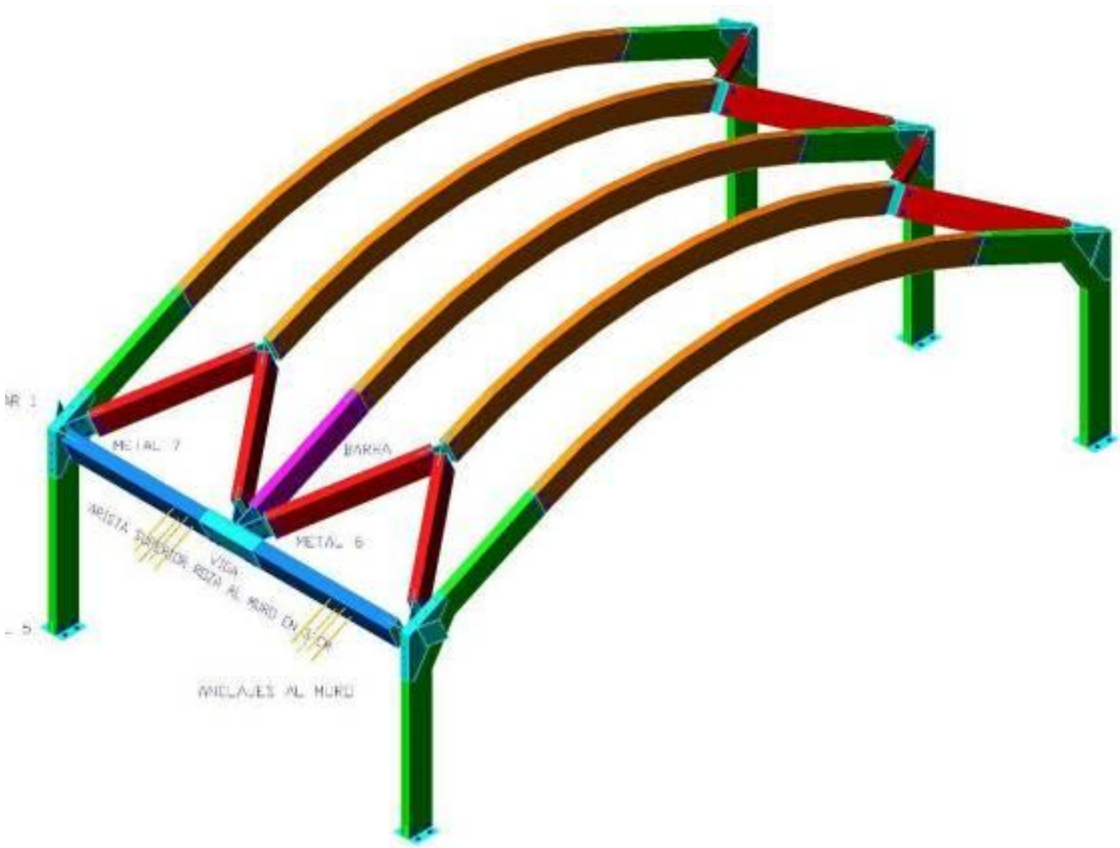


Using wood, we get the minimum structure to cover and define an additional volume for this space.



Barrantes-Cervantes Palace in Trujillo (Cáceres)





The glued laminated timber beams and the galleting of timber planks form the structure over the conference room, placed under the roof.

Besides its high aesthetic quality (the restoration achieved the Wood Building Design Award in Extremadura), timber showed its excellent features in acoustic conditioning.

11. GLASS

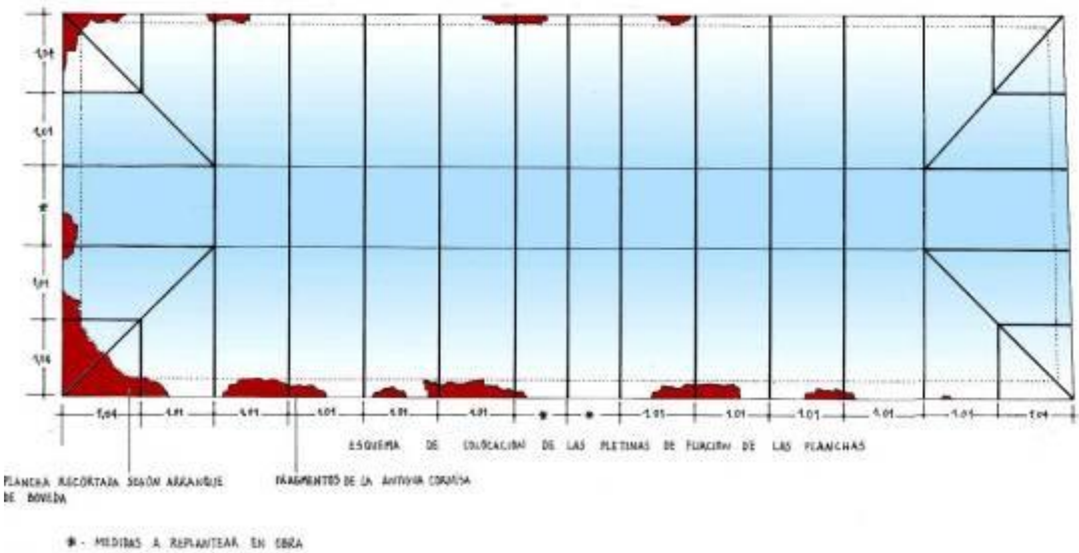
At the same Palace in Trujillo, glass layers sticked with silicone form a 13 metres high “structural wall” to close the courtyard, now used as lobby.

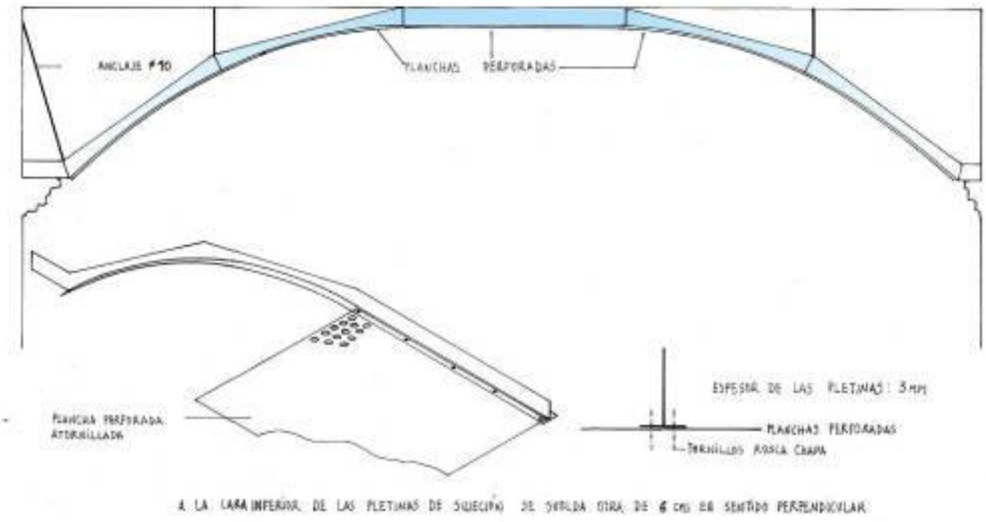
12. STEEL

Sacristy in Sta. María de Requena Church (Valencia)

Even steel can sometimes be considered as the softer and most "conservative" material regarding the building remains.

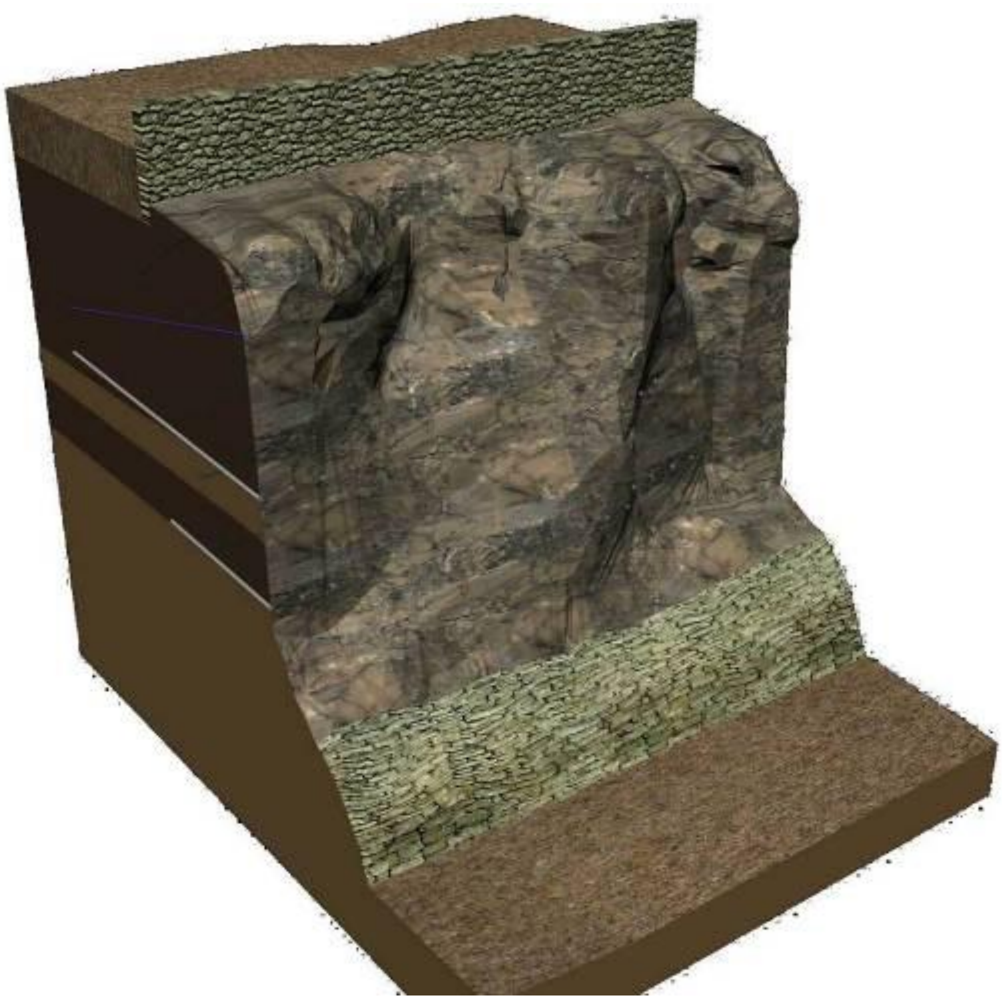
The missing sacristy baroque vault is reproduced with black perforated plate, keeping even the smallest cornice or decorative remain in an "archaeological" way.





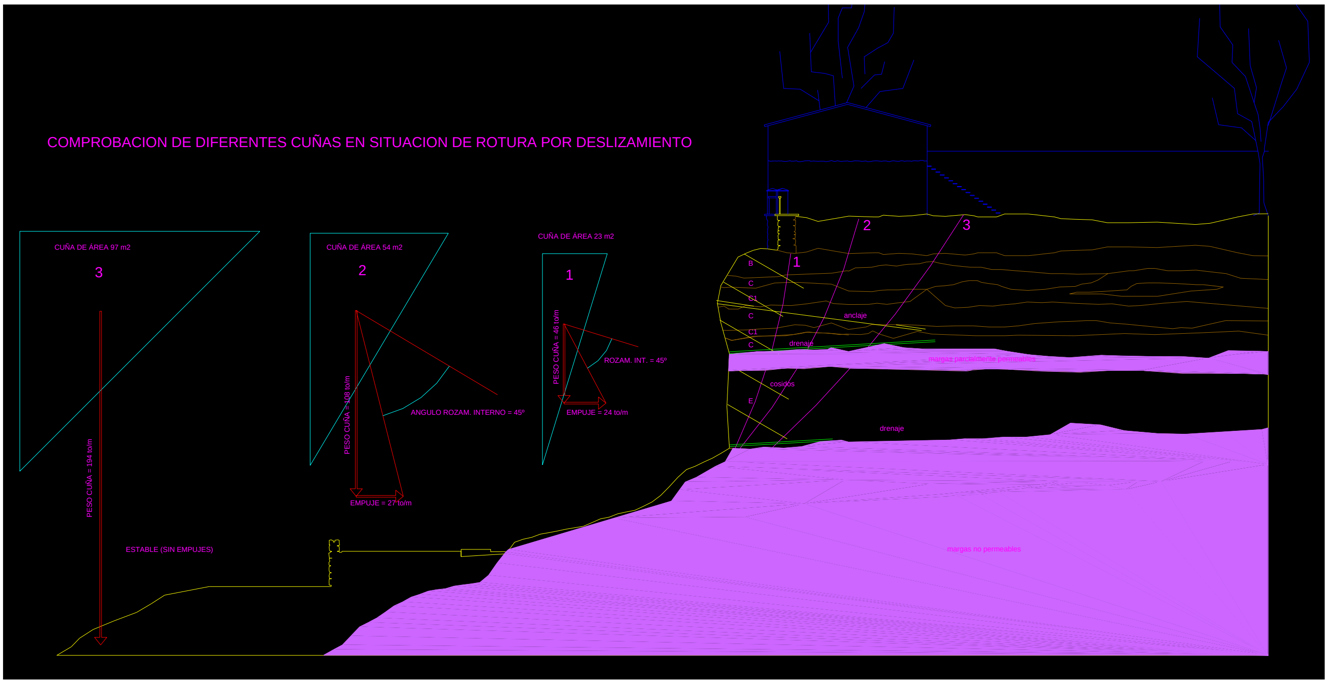
Stainless steel, together with fenolic plywood, is also useful to make minimum structures, as this bridge between the tower and the roof, to approach it for maintenance works.

13. FIBERS



Sta. Marta Crags in Zamora

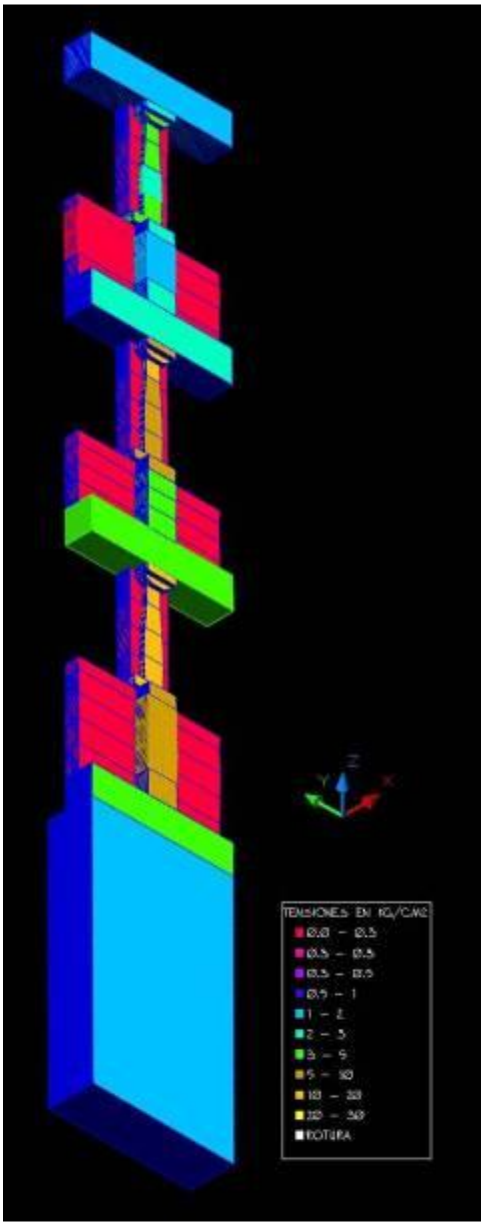
Glass fiber and carbon fiber (at Mahón cliffs) as invisible anchors for stony cliffs, fastening any possible sliding wedge.



Fibers remain unaffected by salts in flowing sewage, allowing what we call “geological restoration” of urban cliffs.

14. NOTHING

“Doña Jacinta” Building at Corredera Square, Córdoba

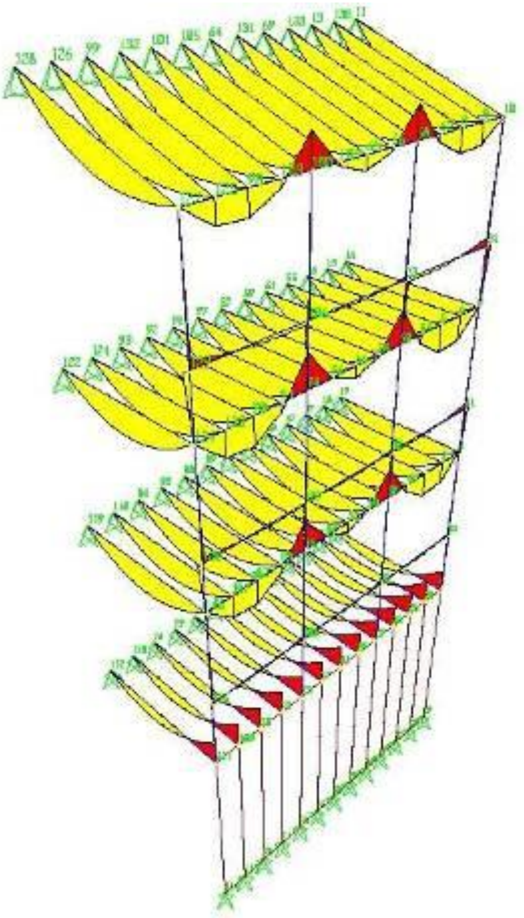


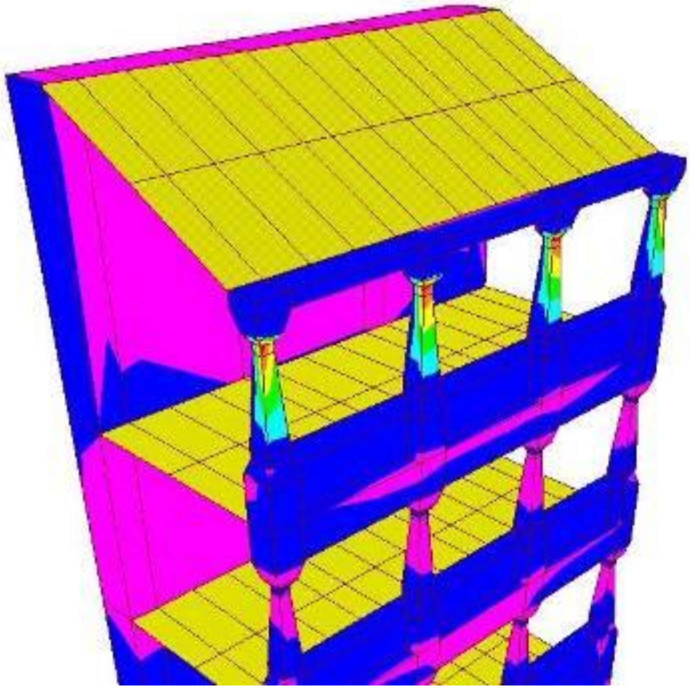
This last fictitious “material” reminds us that often there is no need for intervention.

This building, the oldest in Córdoba Main Square, had been declared “hopeless”, as the material of the load bearing components, the facade columns, is a kind of limestone that breaks under a stress of 80 kg/cm². Furthermore, wood elements looked damaged, and were not well cared for.

The analysis showed a maximum stress to bear of 20 kg/cm², so the remaining strength is over the usual and standardized structural security rates.

This structure only needed to be “understood” to go on working.





We should use technology to minimize the intervention.
Computers should be used to check situations that intuitively seem unstable or unsafe.
Unfortunately, too often a structure that stood for centuries doesn’t pass our specialized analysis, and has to bear reinforcements it did not need up to now.

CONCLUSIONS

Minimum intervention is the less destructive criterion for the building to be restored. As well, using materials that are softer than the original ones leaves the intervention always in the background, and its structural and visual impact will not be harmful for remaining materials, nor for the space itself.

We could always ask ourselves if our intervention on an ancient building has preserved its elements and added new value to it, or, on the contrary, has altered it in such a way that it is not recognizable anymore, as the preserved elements are only incidental… let's think of well-know restorations.

Some related author's publications

1. "Restauración de la cubierta del teatro municipal de Almagro". *Informes de la Construcción. n. 429*. Madrid, january-february 1994. p. 15-22.
2. "Análisis Vectorial Automático en la Restauración de Monumentos". *1st National Congress on Technology in Architecture.* E.T.S.A. Madrid 1994, book nº 2 p. 347- 357.
3. "El acueducto de Segovia". *Informes de la Construcción. n. 437*. Madrid, may-june 1995. p. 5-31.
4. "Análisis Vectorial Automático en la Restauración de Monumentos". *La ciudad y sus murallas.* Granada University 1996, n.2 p. 355-374.
5. "Tecnología previa a la restauración de edificios históricos", *Informes de la Construcción. n. 460*. Madrid, march-april 1999. p. 5-15.
6. "Consolidación y restauración de las Murallas de Atienza. Guadalajara", *Cuadernos del Patrimonio* nº 4, Alcalá University, january 2001.
7. "Biblioteca Municipal de los Depósitos del Sol de Albacete". *DDA Detalles de Arquitectura.* Madrid 2001, p.80-105
8. "Hormigón y vidrio para recuperar el torreón medieval de Castrovido", *Revista oficial del Colegio de Arquitectos de Burgos,* year III nº 7 first quarter 2002, p. 10-11.
9. "Estabilización de acantilados urbanos mediante técnicas de restauración geológica". *Revista de Obras Públicas*. Madrid, march 2003. p. 49-56.
10. "Iglesia de San Miguel Arcángel en Canet lo Roig (Castellón)". *Recuperem Patrimoni.* Valencia, may 2003, p. 100-105.
11. "Termas Romanas de Amador de los Ríos en Toledo". *Restauración y rehabilitación*. Valencia, february 2005, p. 38-45.
12. "La Intervención en las Termas Romanas de Amador de los Ríos nº 5". Arqueología romana en Toletum: 1985-2004. Toledo, april 2005, p. 17-53.
13. "Baños de Tenerías: materiales modernos para recuperar restos antiguos". Baños árabes en Toledo. Toledo, june 2006, p. 69 a 79.
14. "Palacio Barrantes Cervantes, sede de la Fundación Obra Pía de los Pizarro". Rehabilita 06/07. Plasencia, april 2007, p. 48 a 57.

Related web sites

Architecture Office Francisco Jurado: http://www.franciscojurado.es

Article about Segovia Aqueduct: http://traianus.rediris.es/textos/segovia.htm

Subject at Madrid School of Architecture: http://www.aq.upm.es/ee/e96-550/fjurado/welcome.html

Article: Technology in Ancient Buildings Restoration: http://www.tirant.es/monocnt?daId=3