Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

Restoration of thin shell brick domes: the chapel of the 'Hospital de la Caridad'

P. Valcárcel, Jr.[a], F. Escrig[b], S. Muñiz[a]
[a]*Departamento de Tecnología de la Construcción E.T.S., Arquitectura La Coruña, España*
[b]*Departamento de Estructuras E.T.S., Arquitectura, Sevilla, España*

Abstract

The construction of thin shell brick domes is very usual along the Mediterranean zone and presents some very noteworthy characteristics of lightness and strength. The diffusion of this sort of domes has been specially remarkable in Spain from the 13th century and are still being used nowadays.

The great strength and adaptability under load of this sort of domes stands out due to its performance under accidental actions of some importance. In the paper a serious implications of pathology by settlements on the chapel of the Hospital of Charity in Ferrol will be studied. It is a little church made with shell brick domes during the 18th century. Techniques and studies that were executed to its restoration will be also studied.

1 Introduction

The covering of sites with brick sheet vaults is highly often in the Spanish architecture from the 13th century. But from 16th century the long tradition of building in brick of Arabian origin, which is called Mudéjar in Spain, is mixed with the new trends of Italian origin. The result is that brick sheet domes and vaults, that is to say those formed by several layers of bricks joined with mortar (fig. 1), turn into an usual constructive element in the new renaissance forms and are still being used till now. Even in the 20th century the spanish architect Guastavino introduced this technique in USA. Many of this important works are solved with layered brick domes and vaults with a large span.

However, the long lasting and important spanish school of quarrying continued valid in all this period and specially in Galicia, whose quarrymen were famous and in great demand for important works in all the Spanish

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

Empire. It is specially notable the effort that many and important spanish essayists made during the Renaissance and the baroque period to transcribe renaissance architectural forms to stone, which had been performed in brick in Italy. The result of all of this is that both constructive techniques coexist along the centuries.

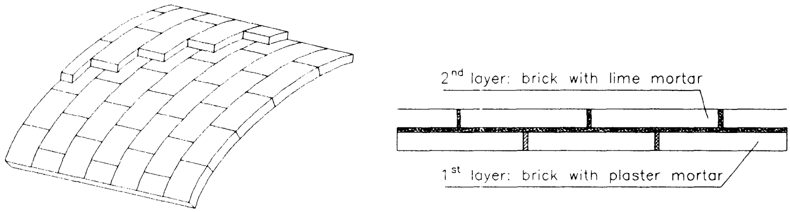

Fig.1.- Brick layered vaults

This situation is normal in all Spain and it is transmitted to the South American countries, giving rise to the most of the big buildings of the viceroyalty period. However, in Galicia, placed in the North-West of Spain, with a mainly granitic land and with an important Celtic culture, stony form are clearly predominant. Brick buildings are very minority and even more when layer domes and vaults are used.

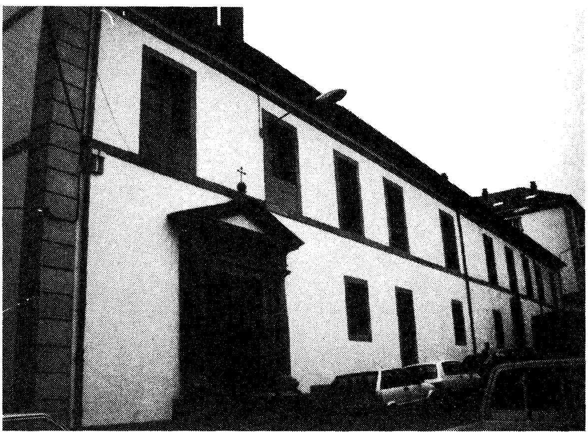

Fig 2.- Hospital de la Caridad

A special case is Ferrol one, city almost of it was built in the 18th century as an important naval base. This caused that the design of the city and the most important buildings were entrusted to military engineers, trained in the new theories of the Enlightenment, so it is possible to find in this city separated examples of what was common in Galicia at this time. One of this buildings is the Hospital de la Caridad (Charity Hospital), built as hospital for poor people. Here it happens a careful design planned by one of these engineers with clear and rational criterions, but performed with very poor materials. Walls are made of plastered masonry, when the usual thing is that at least the front were made of quarrying, and vaults are made of very low-quality brick.

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

2 Description of the building

We can date the chapel of the ancien Hospital de la Caridad in the 18th century. From the structural point of view, it is built with supporting walls in a latin cross ground plan with very short transepts. Over it, it has been built three brick sheet vaults, forming a flat dome over the transept, a dome in corner of cloister over the presbytery, and a cross vault in the back part. The central dome is supported by four basket handle arches, from which the two arch ribs serve as separation and support of the other two vaults and formerets serve as vault for the arms of the transept, which, as it has been alluded before, are very short.

Much later, a wooden covering has been raised over the vaults, which was in rather damaged condition.

3 Noticed pathology

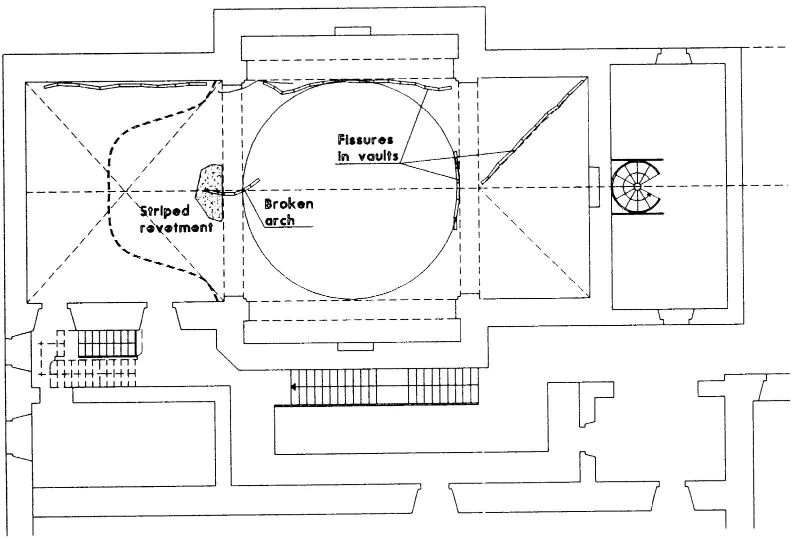

Fig. 3.- Crack damage on chapel

Instead of the low-quality of the used materials, the building in 1979 was in satisfactory condition, specially after a well-conceived restoration to transform it into a cultural centre. However, in the adjoining building, 5 m from the chapel, works to build a big block of houses with five basements for a parking place started. For that, it was performed a basement wall anchored to the ground under the chapel of the hospital. As it is often in this kind of excavations, there was a landslide that made the nearest of the chapel turn in such a way that broke the group of vaults. In consequence, vaults fissured reaching values up to 5 cm wide of fissure and threatening the stability of the

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

whole seriously. In the fig 3, the pathology that presented the chapel can be seen and the fig 4 and 5 show two aspects of them.

Fig 4

Fig 5

4 Research programme

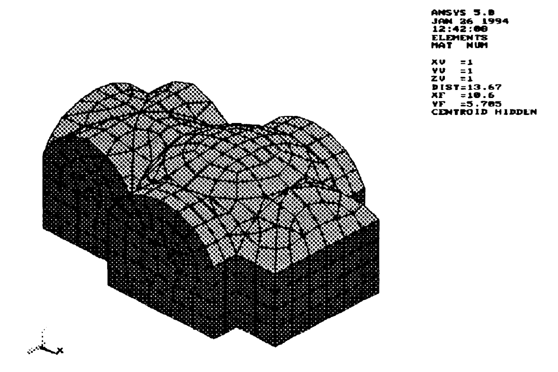

Fig. 6.- Mathematical model.

With regard to this situation, the City Council of Ferrol entrusted a complete study of the stability of the group of vaults and the suitable support of them to the Department of Technology of Construction of La Coruña University. The study of the whole was made using the F.E.M. For that to be possible, at first the plate element was defined comparing the performance of one element formed by three layers, two of them made of brick and one of mortar.

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

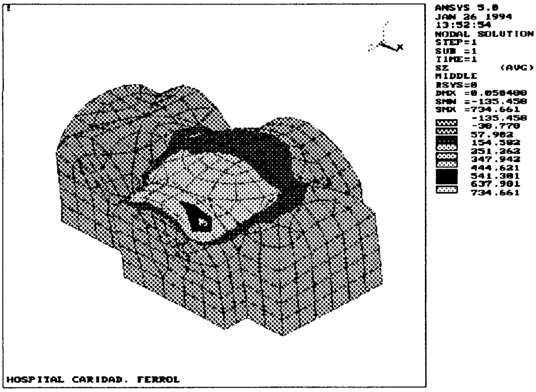

Fig 7.- Horizontal stresses after displacements by settlement

It was made a first modelization to be able to define an equivalent material. Realized researches and the observation itself of guidelines of breaking demonstrated that the mortar formed a pack with the brick and did not imply a weak area of the whole.

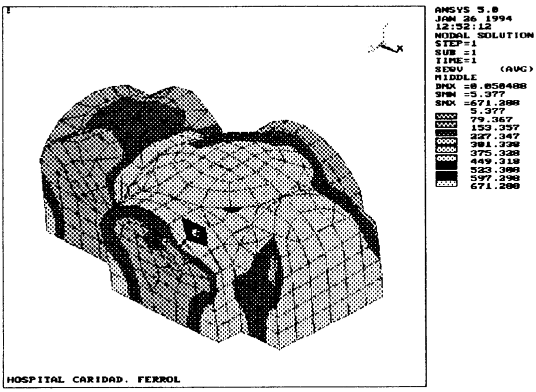

Fig.8.- Equiv. stresses after displacements by settlement

The obtained element was applied to all the vaults and it could be checked that the stability of the vaults was guaranteed, considering fissures closed with mortar of epoxy. However the transverse stability of arch ribs could be awkward from what it was taken the criterion of supporting the upper part of arches by means of a hoop of reinforced concrete.

When de covering was raised it could be confirmed that some timber truss were rested just on the upper part of the dome, that is to say in the most structurally unfavourable point. This fact forced to modify the covering system.

A first study considering the situation of chapel after displacements by settlement was made. The whole was modelized introducing deplacements similar to real ones. Fig 7 shows the horizontal stresses in vaults. It is noteworty that the tension stresses apear in the joint between the central dome and the formeret arch. This stresses are up to 50 Kp/cm2 and could be 73.4 Kp/cm2. The domes made with low-quality brick are not strong enought and in fact is the area fissured as it was described in the pathology.

Fig 8 shows the eqivalent stresses on a perpective of chapel model. Fig 9 show the same in plant and fig 10 in frontal view.

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

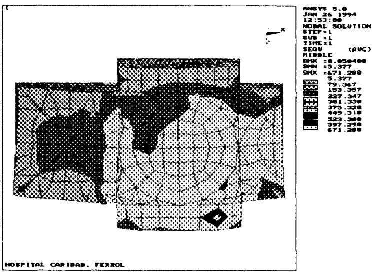

Fig 9

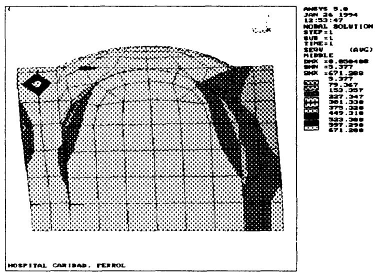

Fig 10

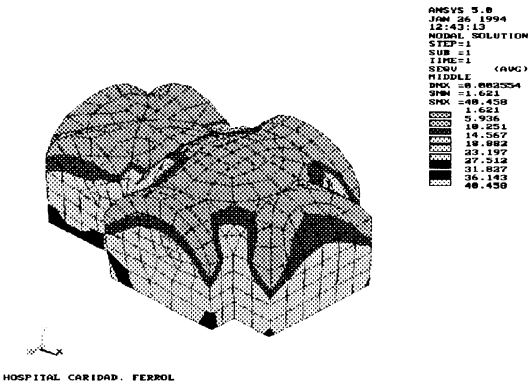

Fig 11.- Stresses under gravitational load

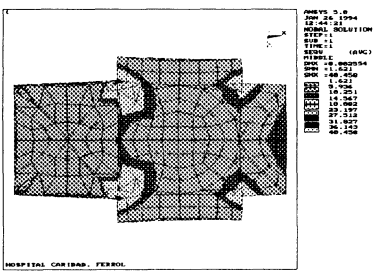

Fig 12

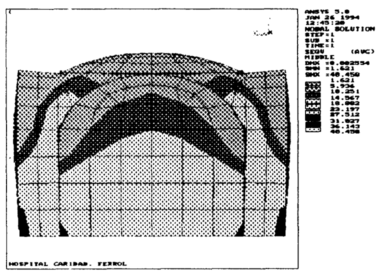

Fig 13

In order to check the stablity of vaults after repair it was necessary to study the situation of the chapel considering fissures closed with mortar of epoxi. The fig 11 shows the equivalent stresses in perpective, the fig 12 in plant and the fig 13 in forntal view.

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

5 Reinforcement system

As it has been alluded before, calculus recommended to tie the upper part of walls with one element of fastening of concrete. In fact the vault itself was hooped with several timber beams that we believe were decisive in order to limit the opening of fissures. Anyway the building was in rather precarious condition and in fact during the initial phase of reinforcement, the chapel continued opening instead of the fact the lateral walls were carefully propped up.

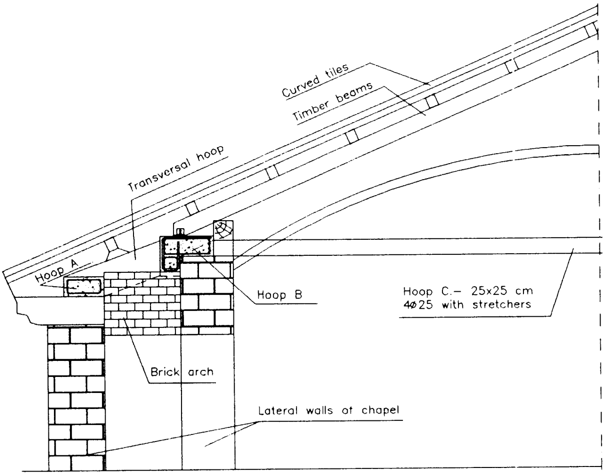

Fig 14.- Reinforcement by prestressed hoops

All of this made us decide to do the hooped with a slight prestressed. It was a question of preventing the enlargement of steel bars when receive the load producing new fissures in the group of vaults. It was also a question of recovering as far as possible the initial condition, closing fissures as the resistance of walls allowed it.

Fig 15.- Construction of hoops

The executed hooped is indicate in the fig 11, 12 and 13. First, sections of hoop corresponding to lateral walls were made and later transversal ones were tensed. They were tensed the first day, afterwards they rested and were tensed again 24 hours later. At the end of one week they were tensed again and the hoop was covered of concrete.

Transactions on the Built Environment vol 15, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

The group of hoops served as support to the new timber trusses of covering. The roof was made in curved tiles, respecting the initial form of the building. This phase lasted three months approximately and when it was concluded, fissures were injected with mortar of epoxy, finishing then the work of reinforcement.

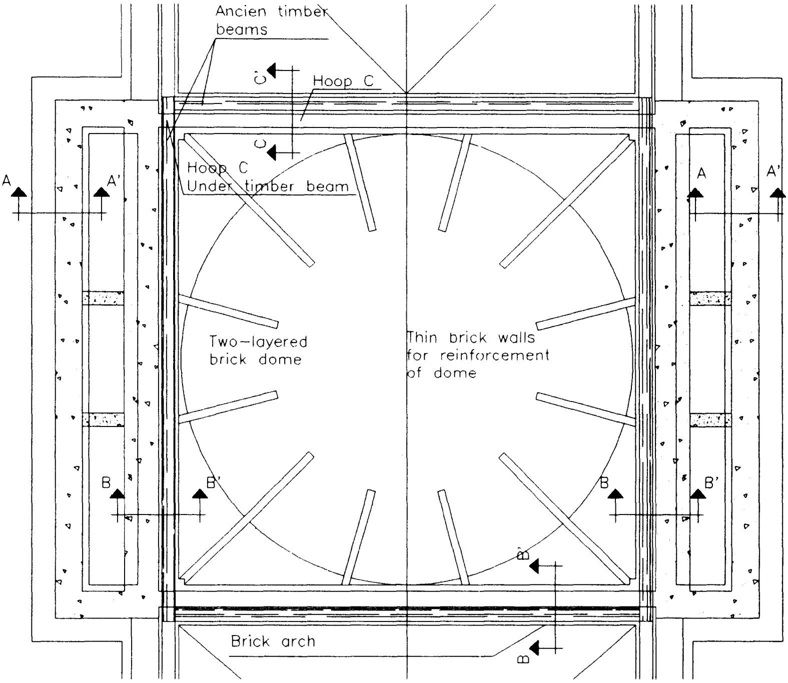

Fig 16.- Design of reinforcement

Conclusions

The proposed work of reinforcement means an action in a building of not very great size, but that presented certain difficulties, due to both the low-quality of materials and the necessity of keeping the elements of tying that had been decisive to limit the damage.

We think that this case confirm what it has been already demonstrated in similar works, the big resistance that brick layer vaults have, even when they have low-quality materials. It also has been demonstrated the effectiveness of injections of epoxy to recover the continuity of these elements.

We also consider the taken solution of prestressing hoops of fastening interesting, even if it is slightly done. Fissures closed to a very small size, nevertheless, after loading the whole it did not fissured again, presenting at this moment an excellent condition.