

ON ARCHES SUPPORTING DOMES STATICAL AND CULTURAL PROBLEMS

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Abstract. In our studies concerning Islamic domes we met the same kind of structural solutions as in some Italian architecture of the 12th century, in particular in the South and in Sicily. We will discuss the structural and historical implications of these findings, especially the interwoven arches.

Research is well underway to assess written documented encounters of the two cultures.

Key words. dome, arch

Mathematics Subject Classification: 01A30

1 Introduction

In June, 18th 827 Muslims landed in Mazara and from Sicily they declared *jihad* against the Byzantines; the war ended in 902 with the fall of Taormina [1]. Only 60 years later, another invasion arose in Messina, led by a Northern population, the Normans. In 11th century, the Normans took control of the entire Sicilian land and of many part of Southern Italy: this domination did not involve Muslim cultural issues. Sicilian and South Italian religious buildings of 11th and 12th centuries witness it.

The architectural language and the building techniques in use are the result of a mix among the different cultures of the Normans as committents, the local workers and the Arabs. The evidence of a massive Islamic influence is clear not only in the buildings but also in many figurative and ornamental elements. This paper will specifically take into consideration the interlaced arches, when used in simple configurations – as in the facades of the Cloister of Paradise in the Cathedral of Amalfi and of the Cathedral of Monreale –, in more elaborated configurations – like those characterizing the cylindrical crown of the bell tower of the Cathedral of Amalfi (fig.1) or the apse of the Cathedral of Palermo – and, eventually, in even more complex cases when the arches are interwoved in the two dimension to create a cupole, known as *muqarnas* – like in the dome of "Badiazza" in Messina or the church of Saints Peter and Paul in Casalvecchio Siculo.



Fig.1: the Cathedral of Amalfi. Highlight of the interwoven arches of the façade and of the bell tower.

2 Morphological and constructive genesis

The formal composition of systems of interwoven arches can be analyzed under two points of view: the geometrical one and the structural one (fig.2).

From a geometrical perspective, these decorative motifs are conceived through the compositional principles of symmetries: formal genesis begins by designing a model, which is repeated several times. The typical model is a zigzag band that, once mirrored, produces the interwoven system of arches.

The second way, the structural approach, is more interesting because is the real constructive mode to design these structures.

The interwoven system of arches is applied both to structural elements and to decorative elements to the structure, such as relief pilaster, pillars, columns, arches, big arches and vaults, pendentif and domes, which, beside the main structural function, mantain also a decorative purpose. These elements are built by means of bricks or stones, enriched sometimes by painted or multicoloured stone panels. These insertions articulate and vitalize the rhythm and succession of blind arches, highlight the relevance and allow a better comprehension of the Arabic influence in the motif of interwoven arches. [2]



Fig. 2: the Cathedral of Amalfi and Villa Rufolo (Ravello). Geometrical and structural analyses.

2.1 Systems of plain interwoven arches: the Cloister of Paradise and Villa Rufolo

To understand the functioning of the system of interwoven arches, bi-dimensional structures are the easiest case study to start with: facades, courts and porches are the best examples because the structure, which is mainly constituted by arches – blind ones in the case of facades –, is easily readable.

Two cases, different in shape but with the same project beneath them, are explained here: the Cloister of Paradise of the Cathedral of Amalfi and the court of Villa Rufolo in Ravello. These examples highlight modalities and building techniques.

In the Cloister of the Cathedral of Amalfi, known as the Cloister of Paradise, the rhythm is marked in four parts where each of them has to be repeated for three times in a row in order to produce a final effect of an overlap and, most of all, to achieve a real diminution of opening equal to a quarter of the acute arc of departure. This is the main aim of this building technique: to simplify the structure, which is highlighted by a light relief of the arches, and to lighten the elements by making use of more support.

The formal matrix of the villa Rufolo is different and more complex. It is a clear example of how to highlight structural elements by means of stone materials. The final project with interwoven arches shows many resemblances with that of the Cloister of Paradise of the Cathedral of Amalfi, beside the different light, which is now divided in three parts.

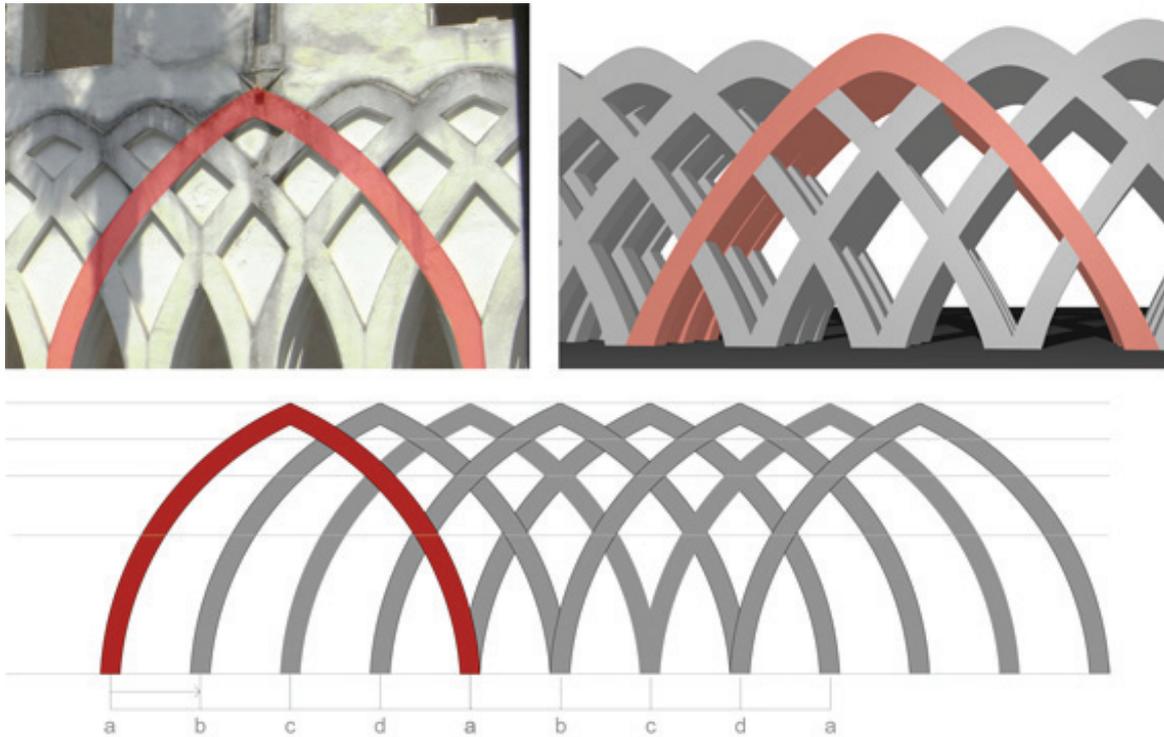


Fig.3: Cloister of Paradise (Amalfi). Compositional scheme.

2.2 Systems of interwoven cylindrical arches

The same sequence of interwoven arches belongs also to cylindrical structures, as bell towers and absides, with a structural purpose.

It has to be pointed out that in cylindrical structures the arches are not plain but they adapt themselves to the surface. Far away from being irrelevant, this consideration is indeed fundamental since the domes own both types of arches: plains and cylindrical. Sometimes spherical arches are used as well: they are known, according to the history of architecture, as three-dimensional arches.

The cylindrical arches show similar procedures of realization compared to plain ones, even in the surface treatment, enriched by reliefs or marble slabs. They differ because of the rotation around the cylinder's axe in addition to the translation of the elements.

A typical example of this architecture is the Cathedral of Amalfi (1180-1276)'s tower bell, where two similar types of interwoven arches are employed: the first, bigger for size, is located in the major tower junction, the second, visible in the smallest side tower, is placed inside one of the minor lancet arches (fig. 4). While the first system consist of 8 interwoven arches, the second one of only 4 of them [3].

The plan scheme appears particularly interesting: as a matter of fact, if we consider only the supporting points of the arches and then draw some segments to link them together and to came to a grafo, what we get is the eight vertex star, a closed drawing that is typical feature orabian culture, in terms of structure and decoration (fig. 5).

The structural function of the arches is emphasized not only by means of clay ware brightly coloured in yellow and green but, most of all, by some openings, round shaped those on the upper

part while large and arch shaped those showing the bells from inside. The same technique is applied in the side towers where the three visible sides are meant to make more evident the great round arch openings.



Fig. 4 Bell tower and 3D model

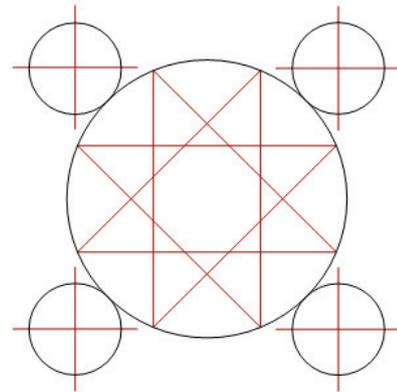


Fig. 5 Graph of interwoven arches

3 Arches supporting dome

3.1 Medioeval period

The intersecting arches motif, surely pertaining to the Islamic culture, was in use in Sicily and Southern Italy even after the conquest of the Normans, although presenting various forms. The most interesting and complex adoption, both in structural and perceivable terms, is employed in sustaining domes. In Sicily there are examples of domes, described by the specialized literature, built through superimposed arches, like the *muqarnas*, the Arabic domes, similar from both a structural and a stylistic point of view. For instance, in the Church of Casalvecchio and in the Church known as the “Badiazza” in Messina, *muqarnas* are employed as transitional elements in their dome.

In Islamic architecture domes with intersecting arches are very frequent as they ensure a wide light roofing made with a structural and building system already known and highly practised.



Fig.6 Castelvechio Siculo Church of SS. Pietro e Paolo – Messina la “Badiazza”

In order to understand the structural function of these elements we have to look at the interwoven arches systems which support the domes.

Schemes shown at fig. 7 are among the commonest within the Islamic architectural culture and are based, as it can be seen by the shadow, on square and octagon geometrical shape.

The arcs systems, projected on the horizontal plane, form, very often, a regular star polygon.

In these cases it is possible to express the intersecting scheme by the Schläfli symbol $\{p,q\}$, where p is the number of arcs and $q-1$ is the number of impostes "skipped" by the arc. With this notation, a set of n non-intersecting arcs is represented by $\{n,1\}$, the first and the last examples of fig.7 are $\{8,2\}$ and $\{8,3\}$, the big tower in the Amalfi cathedral (fig.4) is $\{8,3\}$ and the small towers are $\{4,2\}$. The third example is given by the eight vertex star which is the most important within the Islamic culture.

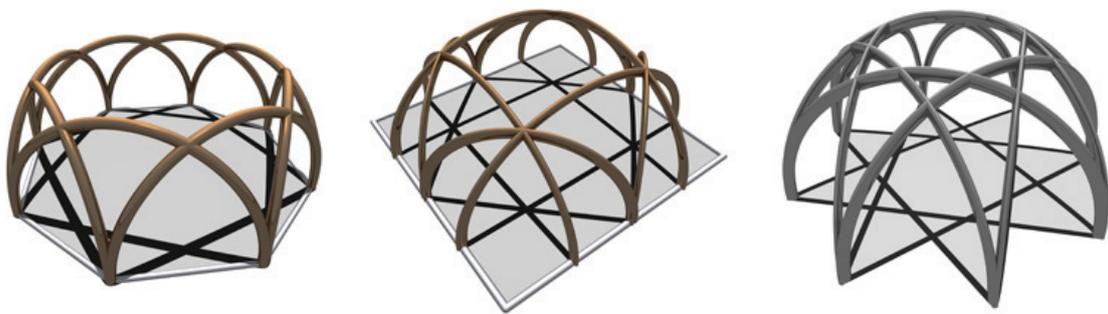


Fig.7 Interwoven arches schemes which support domes

These solutions can be found both in Western and Eastern Islam occasionally characterized by size difference of roofed areas (In the West are much smaller) and, as regards of the material employed, for the final plastering. In Cordoba the three schemes shown in fig. 7 are all employed in the Great Mosque and they can be also found in Iran, in Isfahan Bazar [4].

In this structural systems each arch is contained in a plan that, with some exceptions due to technical reasons, is a round one, placed on the first third of the previous arch. In this way the model is statically correct because of the better resistance of the round arches, when loaded on each side. Conversely, lancet arches work better when loaded on the top. This feature is common in the Eastern culture where, in addition to the intersecting arches system, even more complex systems, which structurally recall *muqarnas*, are adopted.

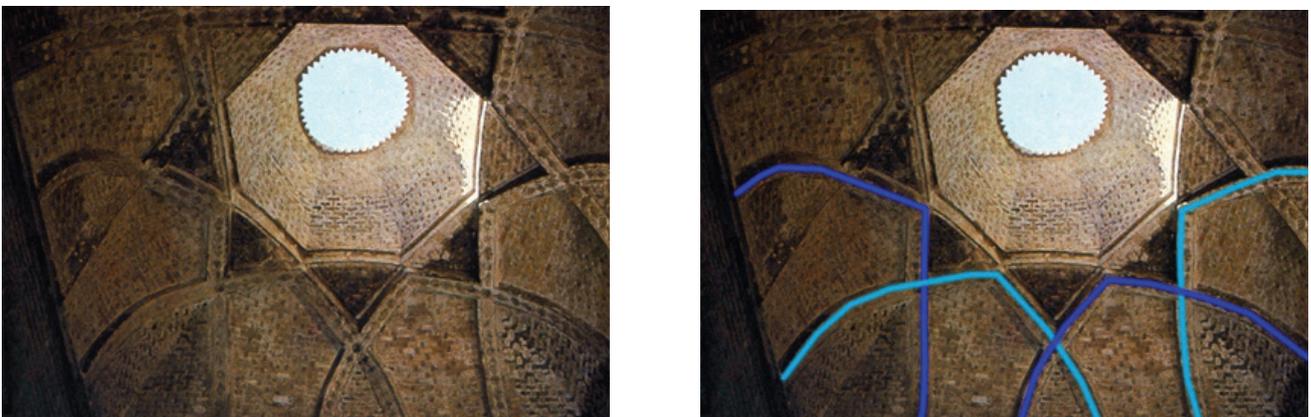


Fig.8 Bazar di Isfahan – cupola e schema degli archi

Indeed, by analysing with more attention the structure of some domes of Isfahan Bazar, we realize that those which may appear like round arches are actually bend lancet arches so to stand on wall orthogonal one to the another. (fig.8)

Here, on each side of the domed area's squared base stand eight arches that, by crossing one to another, form the octagonal impost of the upper small dome, opened in the middle by a circular hole. So, as it often happens in this kind of scheme, starting from the square base we came to the octagonal shape, and the arches system is employed to achieve the Dome.

3.2 Italian Baroque

In Italian Baroque, domes composed of intersecting arches have been designed by Guarino Guarini, architect and Teatino priest.

The architecture of Guarini was considered bizzarre (the term has been already used by educated travellers, when the works was in progress) and was set in use in Turin, an area, which is geographically far away from the lands once conquered by Arabians.

Domes planned by Guarini from 1660s onwards are all arranged on the intersecting arches system as both the Central and the Apse domes of San Lorenzo Church in Turin clearly state. Indeed, these are both very close to the 12th century Armenian religious buildings.

In these examples the infill areas between arches are very often perforated to allow the light inside.

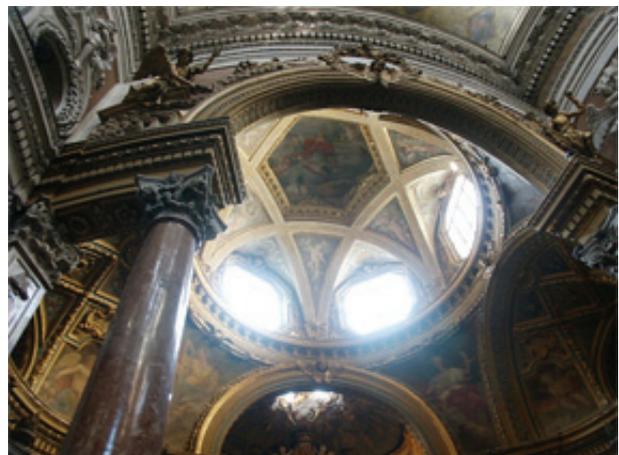
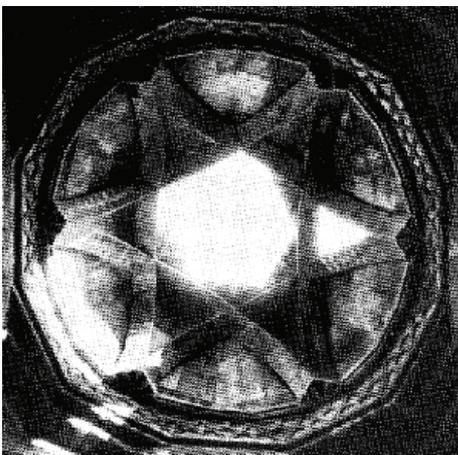


Fig.9 Yerevan's dome and S.Lorenzo's Dome

In the dome of a religious building in Yerevan, capital of Armenia, there is a dome that rests on six round arcs, partially perforated, with an hole in the central part. The impost is circular, unlike the other examples examined so far. It is, also for this reason, very similar to the dome of the apse of the San Lorenzo church, that has been built in the same way, with the same geometries and the same technical solutions for the lighting.

Here there is, very clearly, also the seed for the next and undoubtedly the most important Guarini's work: the dome of the Sindone chapel, whose arches rest on the keys of the underlying arches. It is clear that, in these two cases, the intersecting arches are no more a transitional element between the square and the circle, but they are a projectual and structural theme. In the dome of the

Sindone chapel the structural system is complex and it is hidden behind a decoration made of Frabosa marble. We mention here an hypothesis about the origin of the formal model without penetrating the structural analysis.

Probably the Sindone dome originates from some oriental models present in some cover of the islamic Iraq, made of muqarnas. Only in this region indeed there are perforated elements similar to the Sindone ones. (fig.10)

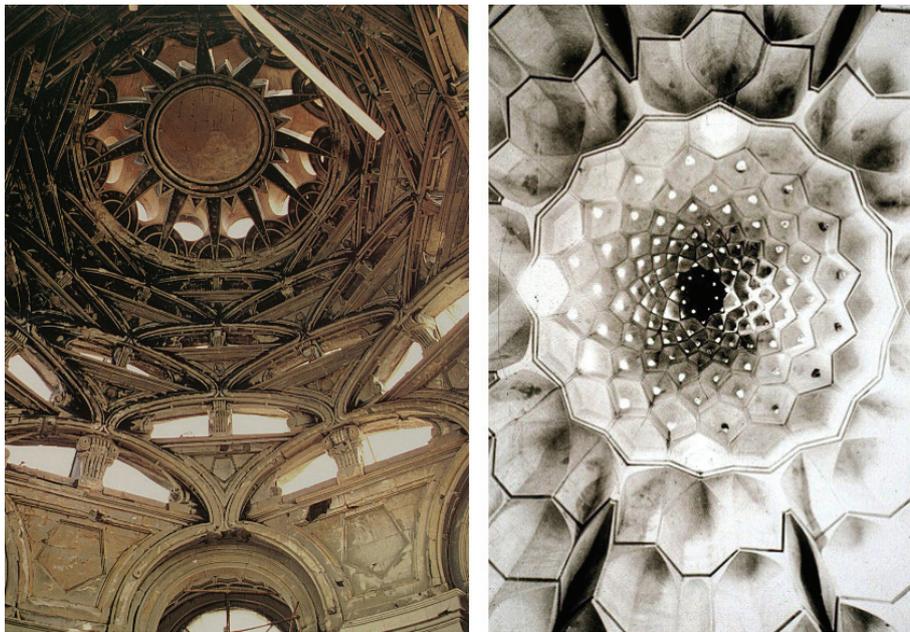


Fig.10 Sindone's dome and mausoleo di Samarra

The utilization by Guarino Guarini of such an architectural model distant in geographical, historical and, most of all, cultural, terms represents a unique case in the Italian architecture history.

Acknowledgement

This paper is based on the research for the tesi di laurea *Composizioni modulari: il caso delle cupole islamiche*, discussed at the Faculty of Architecture of the University of Roma Tre in May 2006, and on the new research for PhD thesis il cui tutor è il prof. Mario Panizza.

The author gratefully acknowledges professor Laura Tedeschini Lalli for supporting this work through all these years, and professor Nicola Luigi Rizzi for his help in approaching the study of domes supported by arches.

I would also like to thank Gian Marco Todesco for the support on the graphics.

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