

## Spanish ribbed vaults in the 15<sup>th</sup> and 16<sup>th</sup> centuries

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Classical historiography separates, aiming at our understanding, historical events in periods discreetly defined. Middle Ages come to an end in 1453 with the collapse of Constantinople and a new period in the history of Mankind, which has been called Renaissance, sees the light: the whole cultural environment which had enlightened the long existence of medieval Europe for centuries seems meaningless and, in a short period of time, transforms itself and imbibes in classical history.

Reality, nevertheless, is utterly different when we analyse carefully the line separating the Middle Ages and the Renaissance. Far from being a clear-cut border, cultural phenomena of both periods intermingle and fuse, sometimes anticipating events, other times keeping alive for centuries. Cultural events ahead of their time, the vanguards, are welcome warm-heartedly, while those that surpass their cultural boundaries are considered late offspring, therefore looked down upon.

One of those remarkable anachronisms is represented by the use, along the 15th and 16th centuries, of ribbed vaults, the unrightfully named late-gothic vaults. In Spain and in the rest of Europe, quite many architects, experts in all the aesthetic and building resorts of classical architecture, insist in the use and development of a ribbed vault of medieval origin. It is stunning to note that, despite the large amount of works built in that style, this long chapter in the history of Architecture has been considered eclectic or mannerist, and, therefore, despised upon.

This lack of interest can be put down on to the apparent anachronism of its existence and to the fact of its surpassing the boundaries of the Middle Ages.

The study of medieval architecture reached its summit with Viollet-le-Duc who, fascinated by French gothic architecture, analyses in a magnificent way the geometrical and building aspects of the classical gothic vault prevailing in the region of Paris along the 12th and 13th centuries. Choisy takes largely up Viollet's explanations and interprets, on expounding the multiplication of ribs in vaults, that the great gothic vault starts its decline when the virtuosity and mannerism of builders put an end to the rationality and simplicity of the first ribbed vaults. Both authors neglect the fact that France, after the 100 Years' War and the Black Death in the middle of the 14th century, goes through such a strong crisis that its population retracts to the density of the 11th century; forests spread out again and occupy the French territory. Its *flamboyant* architecture resents from those dramatic circumstances and enters a period of lesser importance in the European context which will last all along the 15th century.

Spain, instead, expands a lot on the economic side and will reach the top of the European monarchies, its architecture reflecting its economic growth. The influence of Renaissance pervade building techniques in Spain developing a remarkable architecture «*a lo romano*» (made in Roman style) while maintaining spectacular architectural works of medieval inspiration which, surprisingly, was called «*moderna*»

by the architects of the time. Eloquent examples of gothic architecture designed in Renaissance are the cathedrals of Salamanca, Segovia or Sevilla.

This presentation aims at studying in depth the term *moderno* applied by contemporary architects to their designs: modern as opposed to what?. Careful analysis of those architectural samples leads us to appreciate its modernity compared to the gothic style of the Paris region which had inspired in Spain the cathedrals of Burgos, León and Toledo. Our 15th and 16th centuries architects when building their vaults crammed with all kinds of ribs considered themselves utterly different from the constructors of the 11th and 12th centuries' cathedrals.

The present study focuses on those differences seeking to establish a link between the complex morphology of that type of vaults and its construction. In the first place, we will show the composition of the ribs' patterns to further relate it to the shape and volume of the vault surface. This study reveals interesting links between both aspects letting us discover the wise and varied use of the vaulted shapes in complex surfaces which differ a lot from the classical shells of French gothic style.

The study should be divided in three different chapters:

- Morphological analysis
- Modulation
- Volumetry

### MORPHOLOGICAL ANALYSIS

The first thing that comes to mind when we see the arch-like structures of this period are the complex designs that create the array of their fan-traceries. Their designs, however, seem to follow highly defined patterns that we will show afterwards.

Although we do not intend to go deep in the historical analysis of the 15th and 16th centuries' vaults, let us recall that the Spanish ribbed vaults of this period can be grouped in two series, formally very different; in the first place, the vaults of rectilinear geometric designs and, secondly, those that present curvature in their ribs. These two large groups of vaults are connected, respectively, to two main schools of stonemasonry: the Toledo school related to Juan Guas and Enrique Egas and

characterized by the use of straight-lined designs and the Burgos school, with more complex and sophisticated vaults after Simón de Colonia renewed its designs.

From a different point of view, we can also point out that the vaults' designs can be classified in two groups: those whose design is centralized around the middle key and those where the secondary ribs' network interconnects various vaults forming a *continuum* (grid). The polar patterns, the German *sterngewölbe*, had an enormous success in Spain where the overall presence of the crossing arches cuts down clearly the aisles' length. Secondly, the reticular designs, the *netzgewölbe*, so frequent in Central Europe, were scarcely relevant in our country. The exception to this rule is, perhaps, Juan de Álava that designed remarkable examples of vaults where the curved ribs interconnect the different sections creating astonishing and highly sophisticated networks.

After these general considerations, we can conclude that the designs of Spanish vaults follow a set of compositional rules divided in three groups:

- the tierceron on the bisecting line:

The most widely used pattern: once the diagonal arches drawn on the ground plan, the tierceron is placed on the bisector of the angle created between the diagonal arch and the crossing arch. To place the bisector, a surprising geometric construction is used: a circumference is designed around the plan of the vault, the axes of symmetry are prolonged and, where these axes cut the circumference, a straight line linking this point to the vault vertex is drawn; the straight line coincides with the bisector and its layout determines the position of the tierceron.

This way of placing the tierceron can be seen as much in vaults of square plan as in those of rectangular plan. (Fig. 1)

- the regular pattern:

Probably of Germanic origin, it often appears in German vaults as a basis to arrange the complex designs of reticular vaults (*netzgewölbe*). In Spain it is also a regulating element in the polar vaults and in those of rectangular plan where very often the idea of placing the tiercerons on the bisectors is abandoned. Its use gives the possibility of

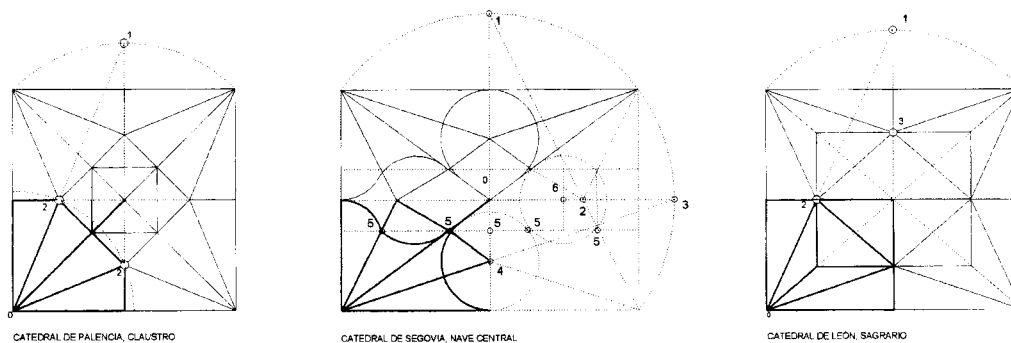


Figure 1  
Three examples of vaults where the tierceron arches are placed in the position of the angle between the diagonal and the crossing or former arch

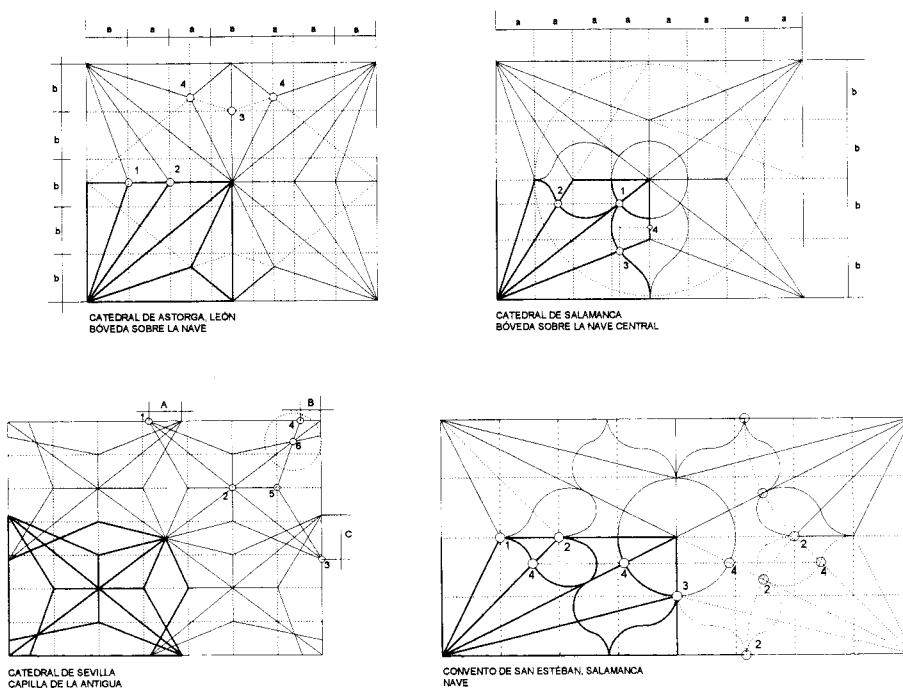


Figure 2  
Four vaults of design established according to a regular pattern

fragmenting the plan of the vault orderly and identifying strategic points to place the vault keys. The frames can be square or rectangular, being the more frequent ones: 434, 634, 834, 8x8 or also 735

or 737, although there are other more complex combinations in which half values are used. One should know that occasionally the two design rules mentioned can occur in the same vault. (Fig. 2)

- the alignments:

This is a secondary resort, used once the large arches have been placed according to the previously mentioned methods. As a general rule, it is used to determine the position of the crossings of secondary ribs such as the curved arches and links, either amongst themselves or with the main arches. The principle of this rule is based on the criterion that all keys must be interlinked and therefore must never be placed at random. (Fig. 3)

### MODULATION

The two fundamental regulating systems on which the medieval composition is based are well known:

«*ad quadratum*» and «*more germanicum*» depending on whether we adopt a geometry based on the rectangle or one based on the triangle. The general composition of the most remarkable buildings of this period, on plan as well as in section and in elevation, was carried out according to these two systems. The regulating system based on the triangle appears freq in Central Europe, especially in Germany, while our country seems to remain faithful to the regulating sketches based on the square.

Apart from these general systems, another interesting aspect stands out: the modulation. Although we do not intend to go into detail thereupon, let us recall the medieval sensitivity to establish series of harmonic numbers that ensured the perfection of architectural works. We are familiar

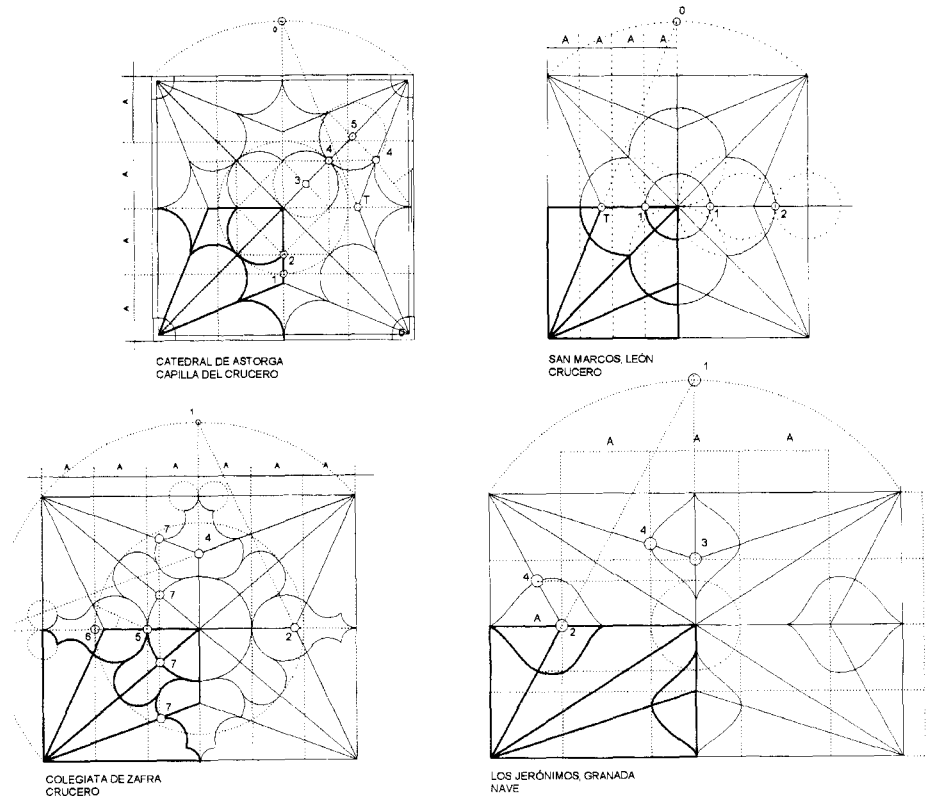


Figure 3

Four examples of vaults where the design is based both on the bisecting line and on the use of a regular pattern. On vaults 2 and 4 the alignments of their subsidiary keys can be seen

with some of these series based on the aureus rectangle, on the square root of 2, etc. However, the series that seems to have been largely used in our country is one that starting from a rectangle of which the longer side is twice as big as the shorter, that is to say with a relation between its sides of 1:2, generates a series of rectangles when having each side increase a unit 2:3, 3:4, 4:5, 5:6 . . . and so on.

The series starts, therefore, from two squares joined in a rectangle in which, logically, the longer side is twice as long as the smaller side. So, each rectangle of the series tempers the differences of its sides until, *ad infinitum*, we would find a single square.

In this huge amount of rectangles there is one reaching the top of perfection: the one with the proportion 3:4, named the *sexquitercia* proportion. This rectangle is formed when joining by the diagonal

line two triangles with sides 3, 4 and 5; we are talking about the famous triangle of Pitagoras that since old times was considered the perfect triangle and even holy by Egyptians.

Besides the above mentioned rectangle, the series contains others of interesting proportions that deserved a specific name:

Dupla	1:2
Sexquíaltera	2:3
Sexquitercia	3:4
Sexquicuarta.	4:5

Out of the infinite rectangles potentially contained in this series, we can affirm, once the measures had been taken, that the format of the Spanish vaults complies mostly with one of those previously pointed out. (Fig. 4)

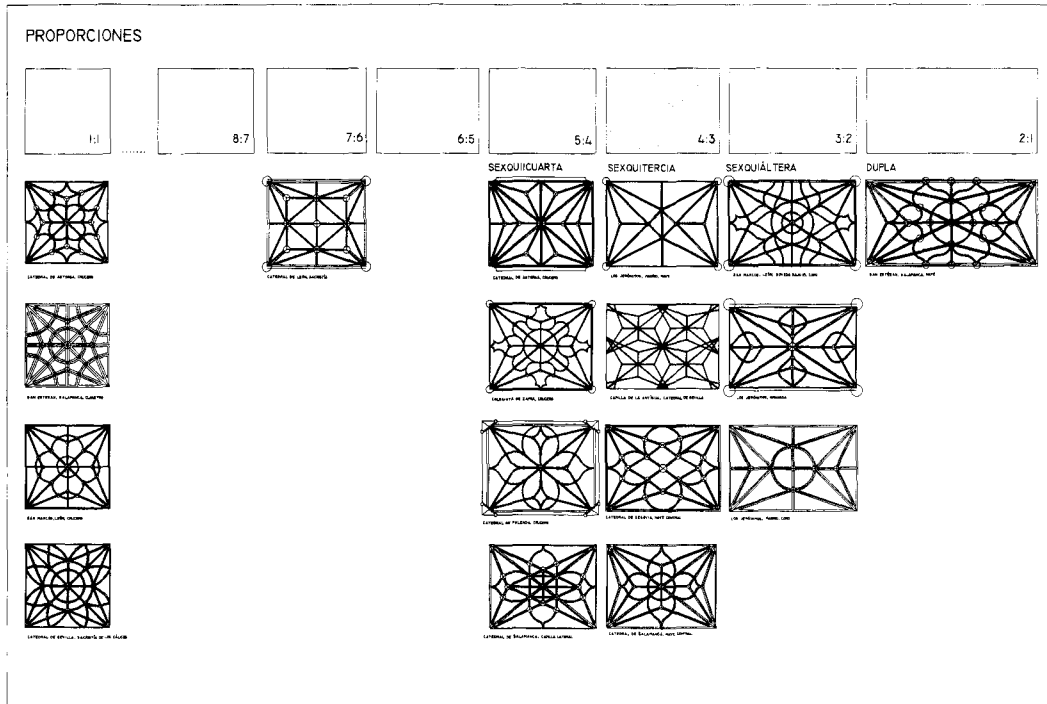


Figure 4

### VOLUMETRY OF THE VAULT

The third part of this presentation focuses on what has been considered one of the most remarkable characteristics in the construction of late-gothic vaults, that is to say the volumetry of the vault.

In either the rectangular or square plan French gothic vault, the diagonal arch was always semicircular. This arch determined the height of the central key and, as a general rule, the height of the keys of the former and crossing arches that were to coincide with the central key; therefore, the profile of this type of vault, in the region of Paris, was basically flat. Although in the south of France, specially in the Aquitaine region, there were vaults with a rather round pattern, the vault previously described is the main classic vault of French gothic architecture.

In the 15<sup>th</sup> century, having elapsed three centuries after the appearance of gothic style in France, the ribbed vault had developed considerably, not only due to its complex design of ribs on the horizontal level, but also to the appearance of a remarkable repertoire of vaulted surfaces to which the architect can resort to carry out the vault.

As we mentioned on other occasions, the increase in the number of arches is justified, from the point of view of construction, as an ingenious attempt to eliminate the centering necessary to build the panel work. Although some hypotheses have been anticipated, we do not know yet precisely how the filling of the panels in the large French vaults was made. Multiplying the ribs solves this problem because it allows the workstone of the panels to rest comfortably amongst them without needing expensive ancillary means of scaffolding and without resorting neither to bulging or vaulting the panels. Because of all this, we can consider the network of ribs like a lost centering made in stone. As it happens frequently in architecture, a necessity imposed by construction can attain higher categories and become a tool of design with a language of its own.

Nevertheless, the increasingly sophisticated designs of ribbed vaults require specific constructive solutions of vault shapes to be carried out; think, for example, of the pointed barrel vaults for the designs in network or of the rounded surfaces for the subsidiary ribs. As a consequence, we find a large repertoire of vaults out of which rigorous measuring has allowed us to identify the following types:

- Horizontal ridge vault:

This type of vault takes up the method of the French vault in which the ridge in the two orthogonal sections is practically horizontal; the profile of the vault may be a straight or a broken line. Some architects seem to favour specially this type of vault, such is the case of the architects Hontañón. According to the way it is built, we could distinguish three types of vaults:

- 1) Traceries in half-circular arches. These arches generally have their centres in the impost lines although sometimes all or some of the centres are placed on a higher level resulting in a raised vault. (Fig. 5)

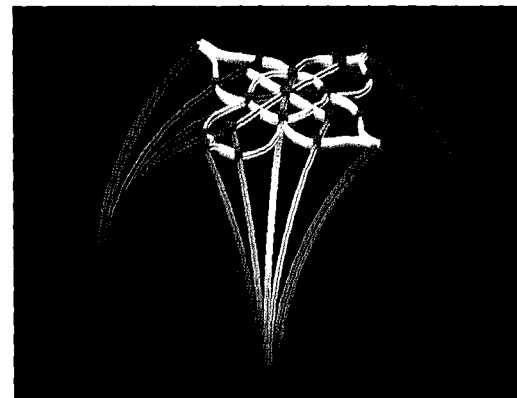
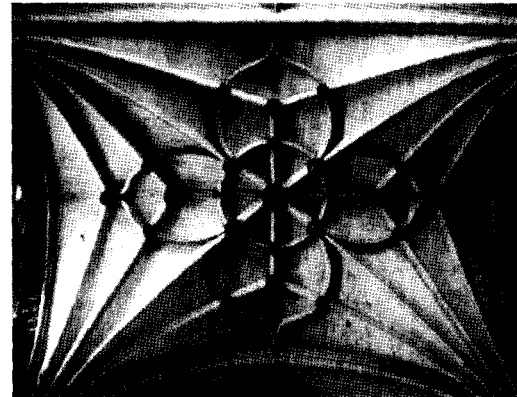


Figure 5  
The figure shows how the shapes of the Spanish rectangular vaults are grouped around proportions next to 4:3, Sesquitercia

- 2) Traceries made with two-centered arches: in this case the ridges are rigorously horizontal and the arches of the tiercerons have two centres. The springing of all of them is the same portion of an oval, which produces an elegant spandrel stone in fan shape.(Fig. 6)
- 3) Traceries of flat key panel: Some vaults whose diagonal rib has been removed make possible the building of a horizontal panel in the central boss; this plan can be square or rhomboid and is situated in the same axes of the vault.

- Pointed barrel vault:

Extremely frequent in Central Europe, it was much less used in Spain. It is very adequate in designs of

continuous tracery or in network. In these vaults the transversal ridge, in the direction of the aisle axis, must be horizontal and the powerful crossing ribs, so typically Spanish, must reduce their section so as not to interrupt visually the length of the barrel.

There are two types:

- 1) Transverse vaults from the top: the panels reaching the former arches start from the central key (Fig. 7)
- 2) Transverse vaults at half level: the barrel vault stands out neatly and the transverse vaults are placed at half level, under the horizontal ridge rib, coinciding with a crossing of tiercerons (Fig. 8)

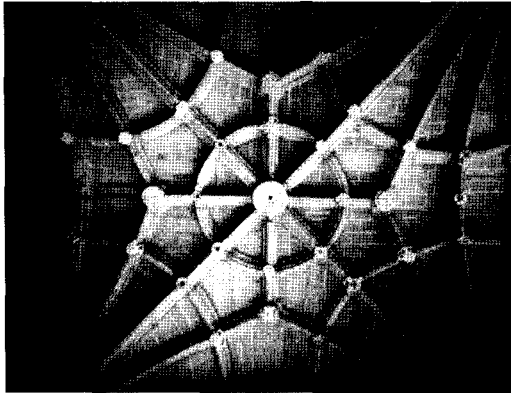


Figure 6  
Horizontal ridge vault with one-centred arches. Cathedral of Salamanca, central aisle. Juan Gil de Hontañón

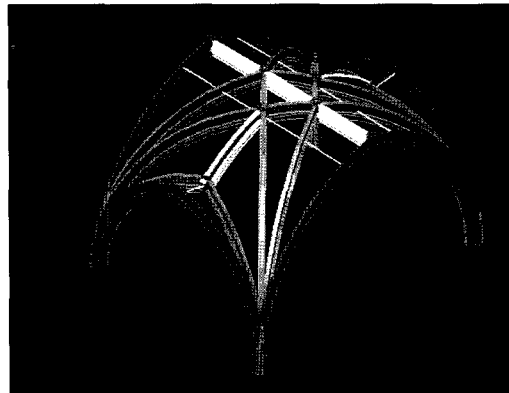
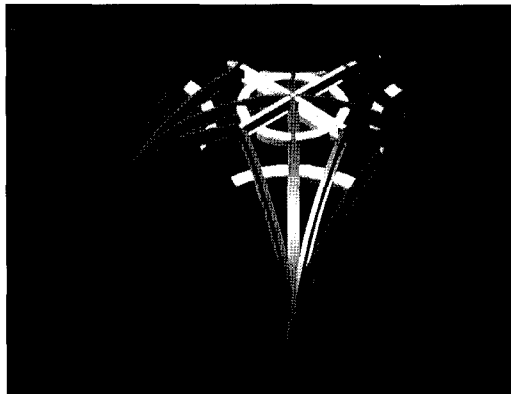


Figure 7  
Horizontal ridge vault with two-centred arches. Monastery of San Esteban, Salamanca. Juan de Álava



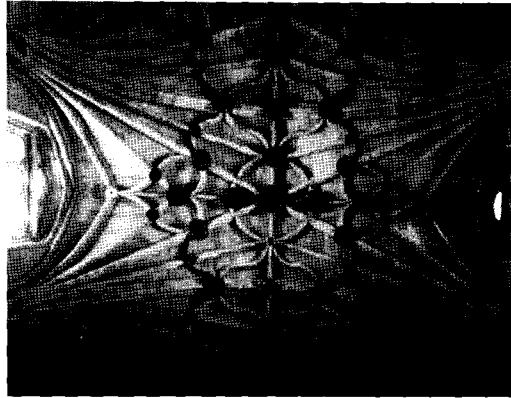
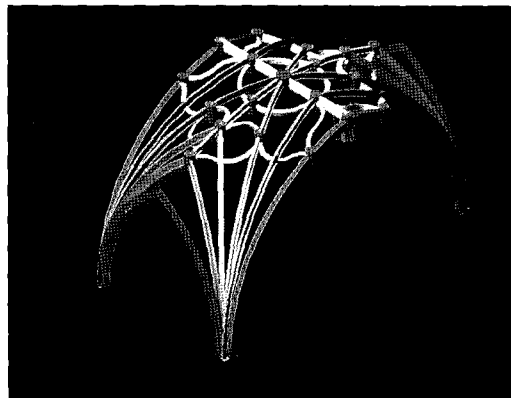


Figure 8  
Pointed barrel vault with transverse vaults from the top.  
Monastery of San Esteban, Salamanca. Juan de Álava



- Curved ridge vault

Very frequent in the south of France, it was enormously popular in our country. It creates a relatively continuous vaulted surface allowing the traceries to develop without the strong broken lines that make up the horizontal ridge vault. The sections of the vault may be unequal letting the former and crossing arches fully free to reach the heights considered appropriate. In Spain, where there is much light and no need of having large glass windows as in northern Europe, former arches may be lower creating side walls more proportionate to a design of windows substantially more reduced than in Central Europe. (Fig. 9)

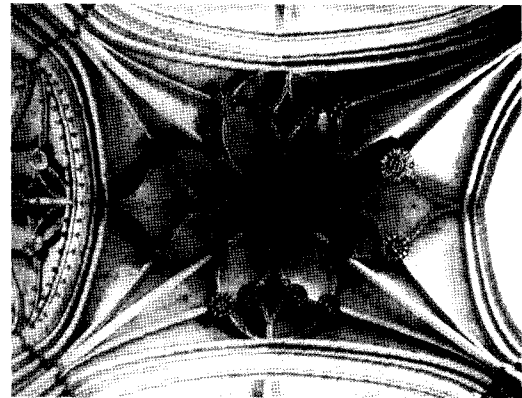


Figure 9  
Pointed barrel vault with transverse vaults at half level. Los Jerónimos, Madrid. Escuela de Juan Guas

- Spherical vaults

The appearance of the circular subsidiary ribs, largely used in the Spanish vaults, resulted in the gothic vault becoming completely spherical: let us draw your attention to the unaesthetic result of a large circular subsidiary rib over the uneven surface of a traditional gothic vault. (Fig. 10)

- Bulging vaults

The rule by which the diagonal arch remains circular and fixes the position of the central key of the vault can be neglected and, on the other hand, the polar key and the rest of the keys can largely surpass the expected heights in a traditional vault. Both listed examples belong to the same architect: Simón de Colonia. (Fig. 11)



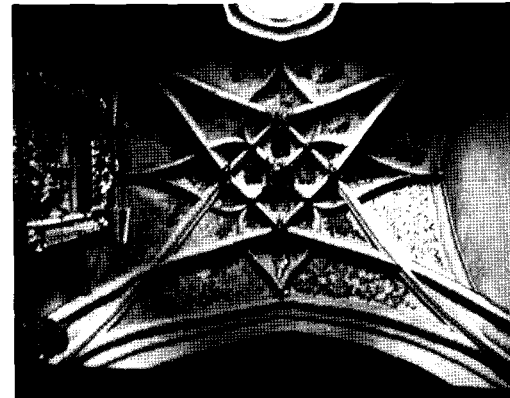
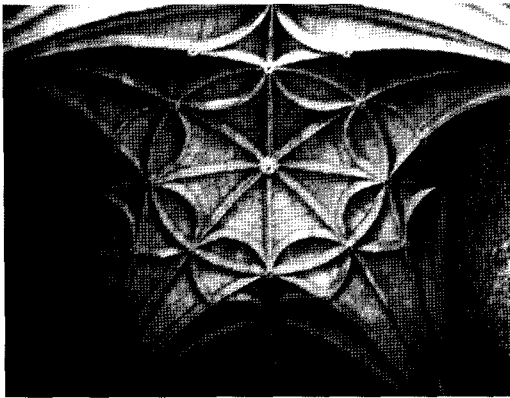
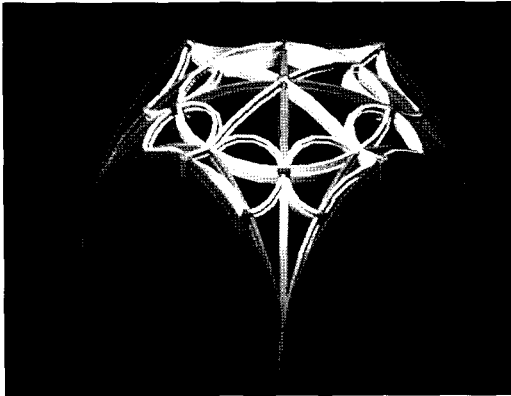


Figure 10  
Vaults of round ridge. Cathedral of Palencia, crossing vault.  
Simón de Colonia

Figure 11  
Spheric vaults. Vestry of the monastery del Parral. Segovia

- Flat vaults

The depressed vaults expanded very much in Spain with the introduction of a typology of a typically Spanish conventual church. The choir, that in Spanish cathedrals occupied the central part of the middle aisle and in most European churches was placed in the presbytery, will now find room in a new place at the far end of the middle aisle, on a high gallery under which access to the church is given. This horizontal level, generally of large dimensions, was supported by a series of vaults that had to be depressed in order not to raise this level excessively and to permit visual communication between this platform situated over the entrance door and the high altar.

Concerning the half-centred diagonal arc, we deal with a flat vault when the central key is kept at an equal or lower height than the radius of this circumference. Depending on with which type of arches the vault is built, we can distinguish two kinds of arch:

- 1) Flat vault of basket arches, made with two-centred arches. (Fig. 12)
- 2) Flat vault of segmental arches, made with parts of half-centred arch: the segmental arches permit a certain degree of freedom since they can spring with variable angles from the impost level; let us remind you that, on the other hand, all the other arches must remain strictly tangent to the vertical line in the impost level. (Fig. 13)

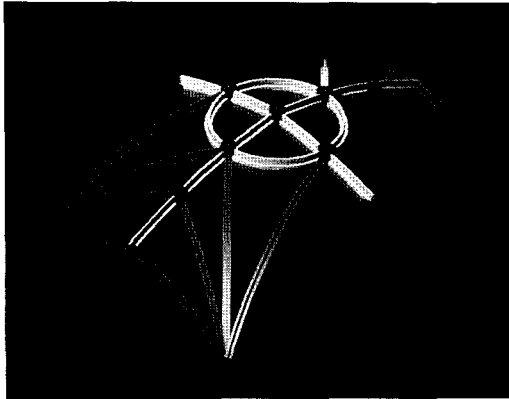


Figure 12  
Vaults of bulging ridge. Cathedral of Palencia, Chapel of la Inmaculada. Simón de Colonia

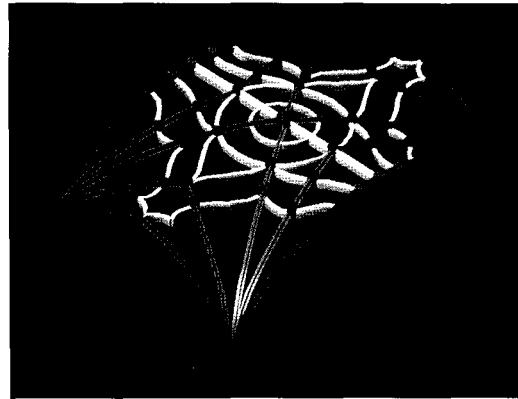


Figure 13  
Flat vaults with basket arches. Monastery of San Marcos, León. Juan de Álava

- Vaults in basket arch

Instead of using one-centred arches, the vault can also be built by using two-centred arches, that is to say segments of oval lines. The vault so constructed presents a flattened aspect because its polar key, in general, does not reach the height of the traditional vault; its rounded surface is very appropriate to draw in circular designs. In Spain they are very common all throughout Andalusia. (Fig. 14)

- Convex vaults

In this type of vaults the central key is lower than the key of the crossing and former arches, that is

why they have descending instead of ascending ridges. The resulting vault is convex and has four trumpet-shaped quarters in the centre. Rodrigo Gil, who had been lavish with the use of flat ridge vaults designed the example we present. In this case, he reverts the concavity of the vault.(Fig. 15)

In Spain, gothic architects of *flamboyant* gothic cathedrals were not only able to develop sophisticated decorative schemes but also presented a large range of structural patterns for the construction of vault surfaces. 15th and 16th centuries ribbed vaults reveal the high skilled use of geometry by builders: without that know-how, it would have been impossible to

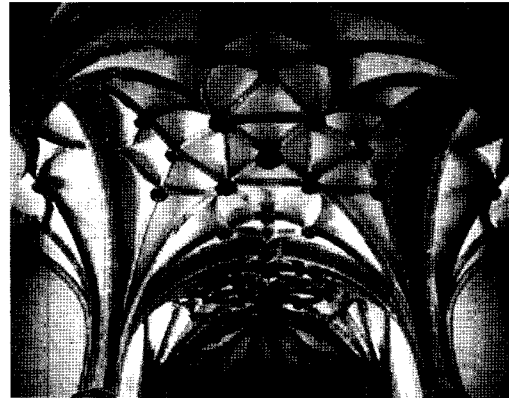
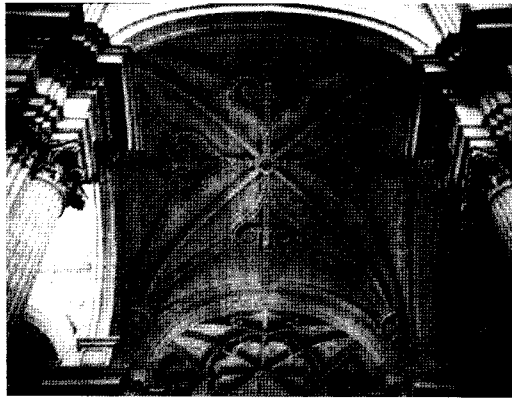
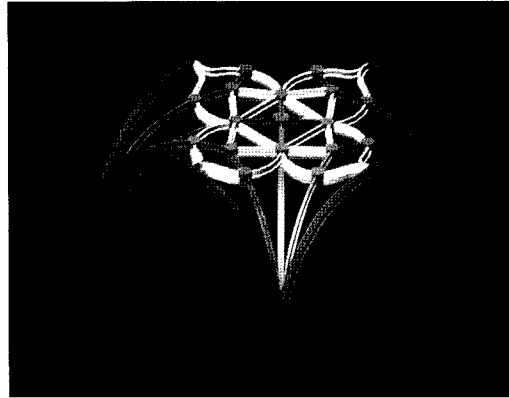
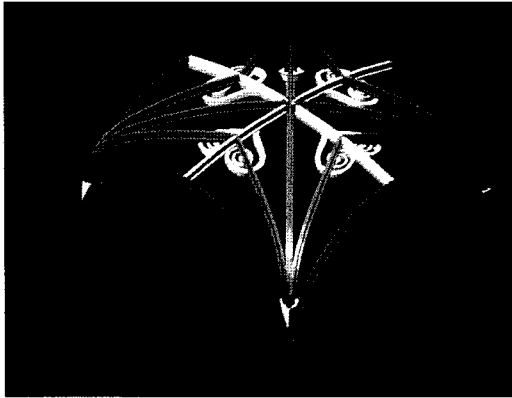


Figure 14  
Flat vaults with segmental arches. Los Jerónimos, Madrid.  
Escuela de Juan Guas

Figure 14  
Flat vaults with segmental arches. Los Jerónimos, Madrid.  
Escuela de Juan Guas

achieve the control of the shape required for the building of a complex vault. Ribbed vaults, Spanish architectural contribution in its most plethoric period in history, cannot obviously be considered a residuary token of the past but one of the most brilliant pages of our architectural history.

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