Proceedings of the First International Congress on Construction History, Madrid, 20th-24th January 2003, ed. S. Huerta, Madrid: I. Juan de Herrera, SEdHC, ETSAM, A. E. Benvenuto, COAM, F. Dragados, 2003.

# On the origin of some «whiteness» carpentry rules

Angel L. Candelas Gutiérrez

In the greater part of Spain during the Middle Ages the construction of wooden roof structures used the system called *par y nudillo* (principal and collar beam), system which, with certain variations, was also used habitually in Northern Europe.

These wooden structures had already come into use by the 13th century, reaching their high point around the 15th century, after which the tradition went into decline. By the late 17th century, the loss of this building tradition had become notable, although roofs of this type were still being built in the 18th century.

The carpenters who executed these structures, and the works themselves, took the name of the light colour —white— of the wood, once peeled and sawed, and hence the term «whiteness carpentry».

We do not really know why this building tradition was lost. In reality, in architecture everything is subject to the changes in society in general, which have a direct influence on tastes and the adoption of different styles.

In the case of Spanish structural carpentry I believe that two circumstances combined to cause its progressive disappearance. On one hand, the absence of texts or manuscripts describing the technique and, on the other, the appearance of successive architecture treatises whose illustrations of roof framing generally reflect the legacy of the Roman tradition —the truss and purlin system. This system became prevalent in a short period of time, in the 17th century, both in Spain and in other European countries.

There are only three known texts about Spanish «whiteness carpentry», in which the configuration of these frames is described. All three appeared in the 17th century, by which time the tradition was already in decline; indeed, López de Arenas notes in his manuscript that his purpose in writing it was to slow its falling into disuse and make up for the lack of knowledge of it among master carpenters.

The aforesaid three texts are the manuscript by Diego López de Arenas *Primera y segunda parte de las reglas de la carpintería*, dated 1623; a part of the manuscript written by Fray Andrés de San Miguel, circa 1640; and the never published manuscript by Rodrigo Álvarez *Breve compendio de la carpintería y tratado de lo blanco*. . . , also from the mid-17th century.

It must be borne in mind that the knowledge required to execute major structures, many of them involving complex tying systems, was transmitted orally within the guild, and possibly with the prohibition of such knowledge being revealed to people outside the trade itself, as was the case in other construction guilds. This fact, apart from the possible illiteracy of the majority of the carpenters, may be the reason behind the inexistence of written texts from the peak period of this carpentry.

In executing these structures the carpenters followed a series of rules which only came to light after the publication in 1633 of the text by López de Arenas.

The interpretation of this text has entailed serious difficulties: it was attempted by researchers from the field of history, i.e. M. Gómez Moreno, and from the engineering and mathematical fields, i.e. Prieto Vives, but it was not truly understood until the 80s, based on research by E. Nuere.

Now, drawing on E. Nuere's findings, we can finally interpret with absolute correction the variety of geometric constructions and the meaning of the text in the above treatises.

This article is intended to take things a step further, attempting to understand how the carpenters could arrive at some of the rules that appear in the treatises, which, while not the fruit of accident, nor did they correspond, evidently, to the application of a scientific or mathematical knowledge that the carpenters of the guild could hardly have possessed.

Very little is known about the way in which the rules used in framing carpentry came into being: the treatises simply explain them, and we still lack sufficient information regarding the frames built over the centuries to answer this question. It would seem logical that the carpenters arrived at these rules after a long evolutionary process in which they would have tried out numerous possibilities; then they would have stuck with those that combined correct structural behaviour with easy application.

Specifically, I shall refer to the origin of two of the many questions that appear in the treatises: on the one hand, the possible origin of a basic rule in the structural configuration: the position of the collar beam and, on the other hand, that of a geometric construction used to obtain the hip section.

In the first case we shall see, based upon structural verifications, that the rule results from the combination of an appropriate structural behaviour with ease of construction.

In the second case, we shall see that the geometric solution, in principle complex, is the result of the interpretation of certain circumstances that the carpenters were able to observe in the construction itself.

## Hypothesis on the origin of the rules for determining the positioning and length of the collar beam

In traditional Spanish carpentry the most common position of the collar beam is at a third of the height, with which the roof projection generates lengths of a third of the span of the faces and another third in the centre —called the *almizate*.

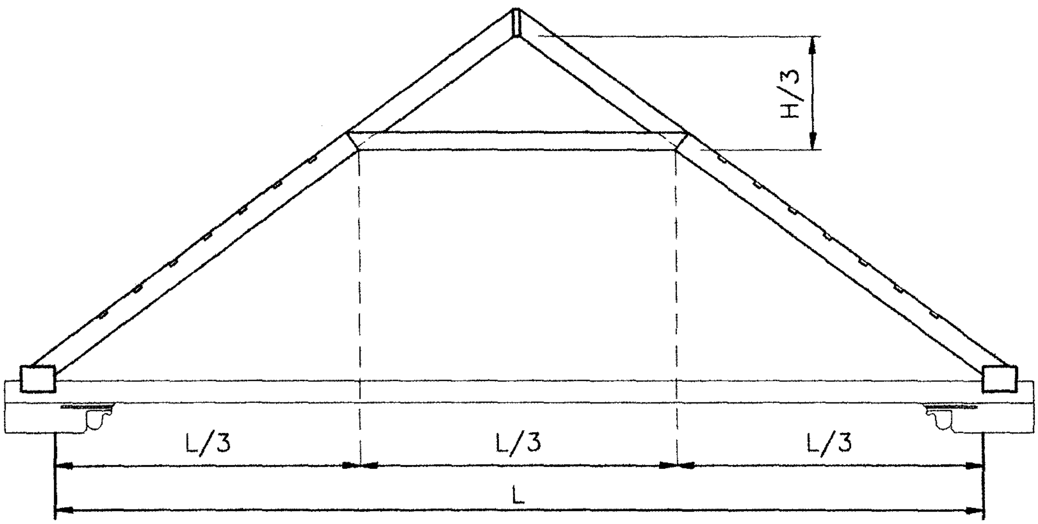


Figure 1
Most common geometric scheme in Spanish *par y nudillo* frames, similar to that described in the Treatises

In the cited treatises, all three authors indicate this position, although in exceptional circumstances, such as those related to ornamentation, other arrangements do occur.

On the other hand, the most common roof pitch is 36º —arrived at by dividing the semicircumference by 5— in keeping with the procedures used for the execution. Figure 1 shows schematically the simplified section of a hypothetical frame designed according to this rule.

First we let us look at questions of structural performance. In order to simulate the possible evolutionary process I have analysed the mechanical behaviour of structures with different placements of the collar beam, trying out those placements which most likely would have been used, and which come of a simple division of the length of the principal. Thus, I have taken into account the position of the collar beam at a third of the height —the most common— at half height and at the upper fourth of the principal.

Figure 2 shows the diagrams of bending moments and axial stress associated with these configurations. Without the need for more exhaustive calculations, any reader with a minimal technical background will be able to understand from these diagrams that the solution of the collar beam at a third is that which results in the most appropriate stress distribution. After observing the real behaviour of other solutions, the carpenters would have arrived at this very same conclusion.

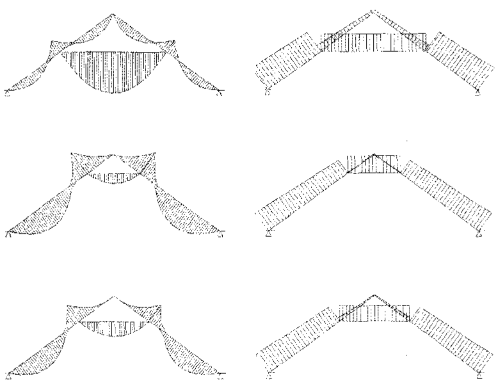

Figure 2
Diagrams of bending moments and axial stress in *par y nudillo* frames with different collar beam lengths (1/2 1/4 and 1/3 of the width)

Nonetheless, the formal characterisation of most of the constructions does not lie exclusively in correct structural behaviour. Without doubt other added circumstances must have come into play for this solution to have prevailed. Here is where the need to attain a regular arrangement comes in, both as an aesthetic recourse widely used throughout history and for the introduction of the ornamental *lacería*.[1]

In fact, in the sizing and distribution of the rafters within the frame the rule of thumb was to separate the rafters by a distance equivalent two times the thickness of the principal. On the other hand, that thickness was obtained precisely by dividing the width of the bay to be covered by a multiple of 3. The thickness thus obtained became the unit of measure used in the construction of the frame.

The plane formed by the collar beams —the *almizate*— is also where the rich and complex polygonal pattern of *lacería* characteristic of the Mudejar construction was habitually incorporated. The latter requires the existence of a regular arrangement that serves as a base for the geometric development of the ornamentation.

Evidently this regularity can be achieved in many ways, but the one used in Spanish framing carpentry, and referred to in the treatises, based on the use of dimensions multiples or submultiples of 3, has the advantage of easy application without the need to make calculations, complex auxiliary constructions, or even plans.

Indeed, the procedure described in the treatises combines correct structural behaviour with ease of construction. The set of the rules cited leads to the regular lines of the *almizate*, capable, on the other hand, of absorbing the horizontal loads on the frame, and providing the basis for laying out the ties.

On the basis of the above, I believe that the origin of the rules for the location of the collar beam and determination of the thickness of the timbers is perfectly in accordance with structural and formal circumstances. Indeed, in Spain, a system was consolidated in which two highly positive factors came together: on one hand, the great stability of the frames and, on the other, having found from a very early date an ornamentation process which offered great variety and richness without altering the basic structural system.[2]

## Hypothesis on the origin of the geometric construction used to obtain the hip section

The other rule I shall address is that which served to obtain the cross-section of the «moamar» hips.

By way of introduction I should refer to a feature that distinguishes Spanish framing carpentry from that of other countries. The habitual procedure in almost all cultures for building a roof of various faces is fit a sloped timber on the edge delimiting one section from another —the hip. In Spain, in addition to this procedure another more refined one was employed, placing a hip on each of the planes that made up the roofs, thus on the edge there appear two adjacent hips. This is what is called the *«moamar»* hip, and it is associated with the prefabrication of the roof planes on the ground and the subsequent fitting of the completely finished spans. Although this is not the subject of this article, it may be said that it is one of the first examples of large-scale prefabrication in the history of construction.

In the definition of the moamar hips, the whiteness carpenters achieved great subtlety and perfection, seeking the correct visual effect. In fact, if we build the hips with rectangular-section timbers, observing the area between them we see that the inner faces of the hips are not parallel, due to different slopes of the spans. Our impression is that they are angled inwards with respect to the fictitious plane formed by the inner edges of the hips. In order to correct this effect, a trapezoidal hip section, known as a *campaneo*, emerged. The three writers explain how to obtain this trapezoidal section in moamar hips. The construction method following is from R. Álvarez:

> De como haras la esquadra De limas fairas . . . Para Sacar la esquadra De lineas fairas se a de tomar un pedazo de madero labrado al marco, que huviere de Yr la madera para la tal obra. Y hecharas en tal pedazo De madero un trazo con la caveza De la Planta Pitagorica, que los Arquitectos llaman Cartabon de aquatro, en el ancho o tabla; Y echaras otro trazo con la caveza del cartabon De Armadura que junte con el de aquatro, Y luego Daras la Buelta al madero por el canto, y adonde fenezen los trazos que Yciste en elaz que fueron a parar al canto hecharleas Dos trazos con la cola del alvanecar a que Armaren la tal obra, ora sea cuadrada, ora ochavada: y el claro o cantidad que ay de cola a cola del alvanecar la tomaras en un compas, y por la esquina del madero pondras la tal medida poniendo la una Punta del conpas en trazo quadrado y con la otra aras un Punto adonde llegare que sera entre el trazo de la caveza De la Armadura y el quadrado, y este viage que haze este trazo Con la esquina Del madero es la esquadra de lineas fairas como lo Muestra su figura. La letra A. corte quadrado la B. caveza de armadura la C. y D. las colas del alvanecar la E. el desvio de las dos colas la F la horma de la esquadra. (Álvarez, R. 16??, 39v- 40).3

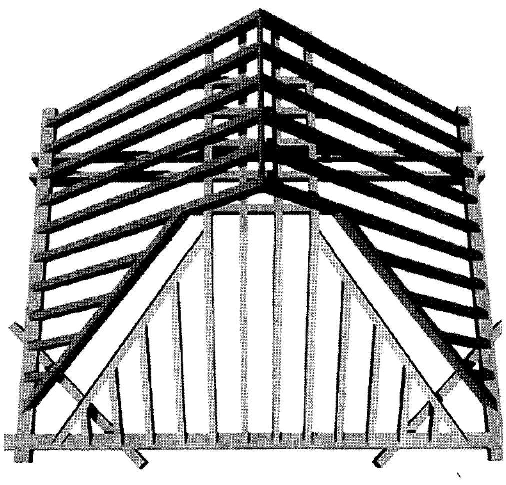

Figure 3
Spanish «par y nudillo» roof frame. Note the double *moamar* hips in the foreground

The procedure that Rodrigo Álvarez describes in this text is similar to that employed by López de Arenas, although better. Arenas obtains the amount by which the upper part of the hip must be widened. Álvarez, employing the same procedure, constructs a special square for this purpose.

The aim here is that, once the structure has been executed, the inner faces should be parallel, which can be achieved with a number of systems. But if we also want symmetry with respect to the diagonal of the building, the only possibility is that the inner faces, once fitted, should be vertical. That is what is achieved, with absolute geometric perfection, following the process described by the three authors.

Here I will not go into the interpretation of geometric construction resulting from the cited paragraph, question which, on the other hand, was addressed by Nuere (1985), though using the description by López de Arenas.

Once this interpretation is known, it is relatively easy to achieve the arrangement described in the treatises, but what is not so evident is how the carpenters arrived at this rule. Researching this question, I have formulated a hypothesis based on the geometry that the carpenters could observe in their first attempts to achieve parallel inner faces on the moamar hips.

Figure 4 shows the how a moamar hip joins the first principal of the structure. The left-hand image shows a rectangular-section hip and, at the right is the trapezoidal section sought by the carpenters.

In my opinion, some carpenter must have realised that in order to achieve vertical inner hip faces he had draw the lines from the edge of the joint between hip and principal with a *cabeza de la armadura*[4].

With this line, they could then draw on the face of the principal the sloped section of the hip they wanted to use, as we can see at the left of figure 4. However, what they needed was the straight section of such a hip. Nowadays this question might seem to have a simple solution; in reality it is no more than the folding of a section over a plane. But at the time they did not even work with plans, nor did they have knowledge of descriptive geometry and, as occurred in the formulation of other rules, they had to use the construction elements themselves as a basis for measurements and work processes.

I imagine that what some clever carpenter would have observed would be something similar to that shown in figure 5, where we see a plan view of the joining of a principal and a hip (next to which is the projection of the joining of a hip and principal).

Effectively, the carpenter, standing on the frame, could see that in the sloped section the added distance A-B could be obtained with «Cartabon de aquatro, en el ancho o tabla; y echaras otro trazo con la caveza del cartabon De Armadura que junte con el de aquatro».[5] And he might also realise that drawing two lines parallel to the face of the hip —achieved with the angle defined by the set square known as an *albanecar*— he could obtain the real dimension of the upper face of the hip.

All that remains is to calculate the distance between the two lines B-D in order to obtain the thickness of the timber from which he had to start in order to then cut the sloped face, and hence be able to prefabricate the hip with absolute precision before fitting.

On the other hand, Rodrigo Álvarez (16??) includes in chapter 43, dedicated to obtaining the campaneo of the hip, two drawings (fig. 6). The first

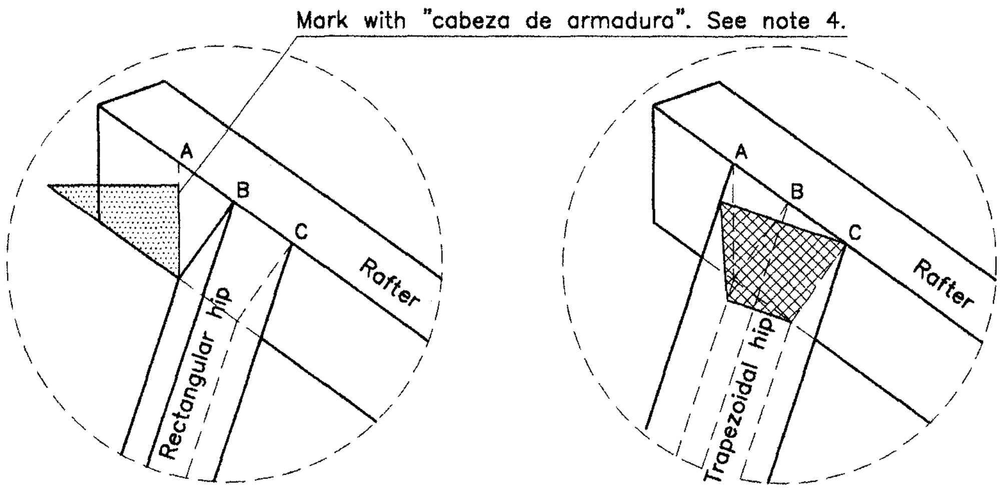


Figure 4
Joining of a *moamar* hip to the first principal of the structure, using straight-section timbers (left) and with the sought-after trapezoidal section (right).

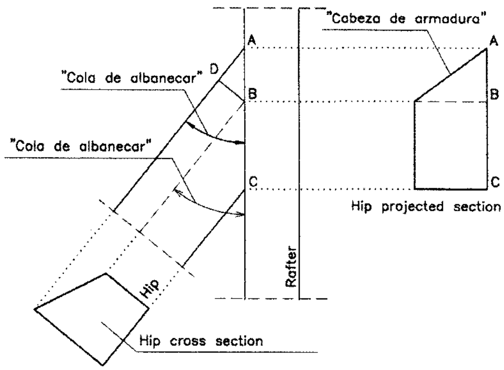


Figure 5
Plan view of the joint between hip and principal

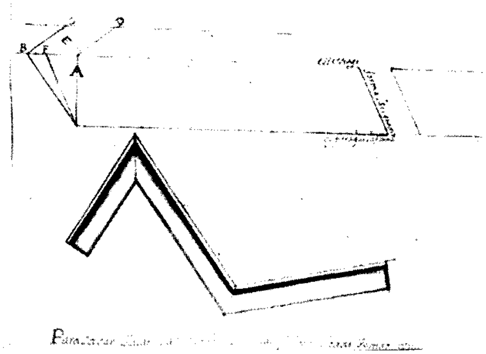

Figure 6
Drawings that appear in chapter 43 of the manuscript by R. Álvarez

is the graphic construction of the process he describes in the text cited above and to which the author himself refers. The text does not mention the dotted line which, as a second drawing, appears under the previous construction. That aroused my curiosity; convinced that this line must be in some way related to the campaneo of the hips, I did a series of geometric verifications based on the original manuscript and found that the angles formed between the lines in the drawing are precisely the angles, acute and obtuse, (fig. 7), that Álvarez obtains for the campaneo of the hip in the first drawing.

Thus, I believe that what Álvarez intended with the dotted line in the drawing in chapter 43 of his manuscript is a tool, a square, which would be built for each frame, with objective of facilitating the

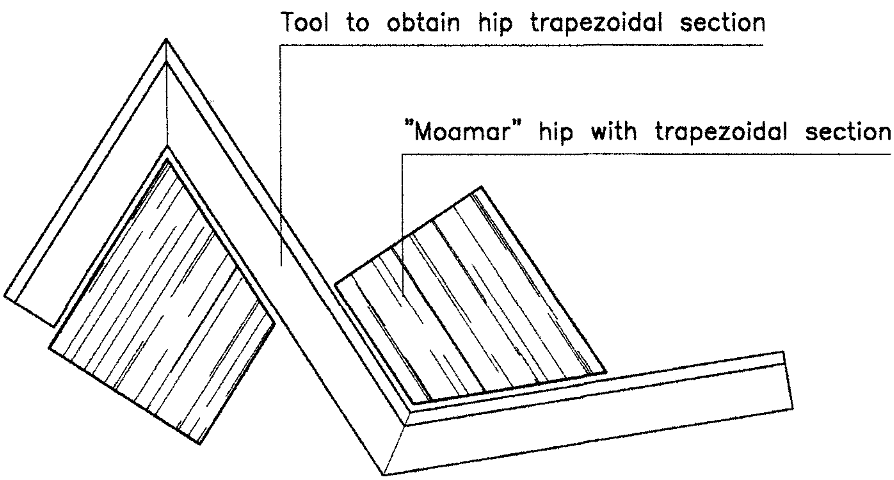


Figure 7
Interpretation of the lower drawing in figure 6: the dotted line drawn by R. Álvarez in chapter 43 could be a square for aligning the campaneo of hips. The angles of the dotted line coincide with those which define the bell in the upper figure. It is, therefore, a tool

execution of the hip section. This square would be placed at regular intervals to verify and obtain the uniformity of the section throughout the piece. Perhaps it is to this that Álvarez refers when, at the margin of the drawing, he writes: *«this line forms the square // and here the form»*.

Or comparative purposes, I wanted to reproduce the geometric construction which for the same objective —obtaining the campaneo of the hip— López de Arenas includes in his manuscript of 1619 (fig. 8). Expressing himself in different terms and with a different graphic representation, he obtained the same hip dimension as in the cited text by Rodrigo Álvarez.

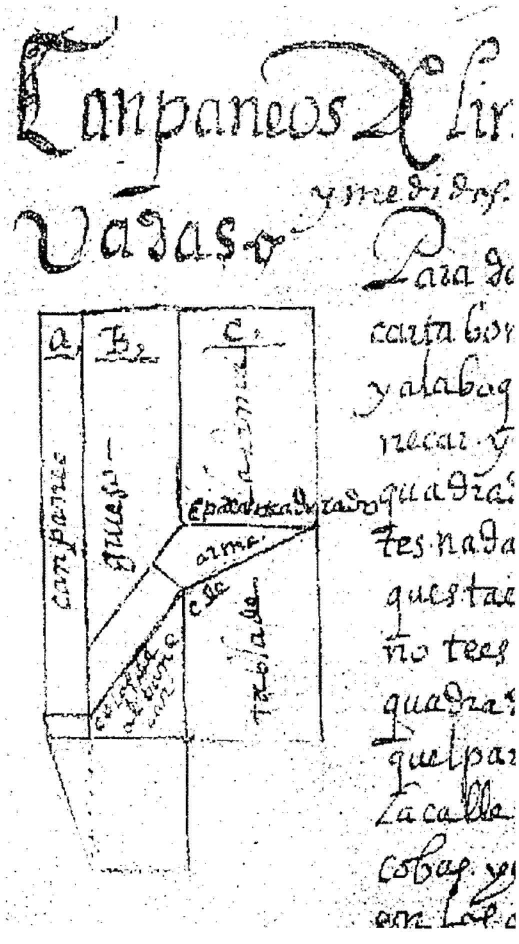

Figure 8
Construction by López de Arenas (1619) for obtaining the campaneo of the hip. Page 7v of the manuscript

These differences in expression lead me to think that Álvarez did not come to know this process through the texts by López de Arenas, and that he had certain experience in the execution of frames with moamar hips. This fact, along with other similar verifications, demonstrate the originality of the text by Álvarez, although it includes fragments of text copied literally from the treatise by López de Arenas.

## Notes

1. The Spanish word for geometrical decoration of straight lines forming intersecting polygons and star shapes. Inherited as a decorative motif from Moorish sources, it was much used by Mudéjar craftsmen in Spain and Portugal.
2. This situation is rather unique in European carpentry. The greater pitch of the roofs in central Europe, determined by climatic conditions, leads to significant stability problems, and thus the great variety constructional arrangements that appeared outside Spain. Spanish carpenters were able to dedicate their efforts to perfecting the symbiosis between structure and ornamentation.
3. This text is difficult to understand in Spanish, both for the terminology and the syntax. It is thus practically untranslatable.
4. Drafting instrument: set square with an angle equal to the pitch of the roof.
5. Which might be translated as: «Mark a 90° line on the thickness, and another with slope of the frame»: the resulting triangle is the increase in section of the hip projected on the principal».

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